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Strategic Evaluation of University Knowledge and Technology Transfer Effectiveness

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by

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Abstract

Academic knowledge and technology transfer has been growing in importance both in academic research and practice. A critical question in managing this activity is how to evaluate its effectiveness. The literature shows an increasing number of studies done to address this question; however, it also reveals important gaps that need more research. One novel approach is to evaluate the effectiveness of this activity from an organizational point of view, which is to measure how much knowledge and technology transfer from a university fulfills the mission of the institution. This research develops a Hierarchical Decision Model (HDM) to measure the contribution values of various knowledge and technology transfer mechanisms to the achievement of the mission. The performance values obtained from the university under investigation are applied to the model to develop a Knowledge and Technology Transfer Effectiveness Index for that university. The Index helps an academic institution assess the current performance of its knowledge and technology transfer with respect to its mission. This robust model also helps decision makers discover areas where the university is performing well, or needs to pay more attention. In addition, the university can benchmark its own performance against its peers in order to set up a roadmap for improvement. It is proved that this is the first index in the literature which truly evaluates the effectiveness of university knowledge and technology transfer from an organizational perspective. Practitioners in the area of academic technology transfer can also apply this evaluation model to quantitatively evaluate the performance of their institutions for strategic decision making purposes.

Dedication

I would like to dedicate this work to my mother,
one of the greatest mothers in this world.

To my beloved wife, Huong Nguyen, and our
wonderful children, who supported me
during my study with love and patience.

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CHAPTER 1: INTRODUCTION

1.1 Research Interest

Technology transfer has been a major area of research and practice in technology and engineering management since the rise of this field. Technology transfer helps to bring research results from the labs into commercial application. The Triple helix theory posits that innovations are originated at the interface among government, academia and industry. In that interaction the government and academia are acting as important sources of new ideas that are transferred to industry. Much effort has been spent by the research community on investigating these interactions before and after the introduction of the theory. However, the field is still open to more research due to its early stage as opposed to other management fields. While other directions are as important and needed, this study is focused on exploring technology transfer from academia to industry with the specific question of how the effectiveness of technology transfer from universities to industry is evaluated. The study reviews previous approaches in the literature and comes up with a new approach to the problem.

1.2 Research Scope

The general goal of this research is to develop a new approach to the evaluation of effectiveness of technology transfer from university to industry. This study approaches the problem by examining a comprehensive list of university technology transfer mechanisms, not just one mechanism or a group of mechanisms, and sees how they help contribute to the achievement of the university's mission. Due to the large amount of data that need to be collected and some uncontrollable challenges in accessing and obtaining those data from the entire university, the study is developed and applied only to Science, Technology, Engineering and Medical schools within the university. The model, however, can be modified and applied to the entire university following the same procedure. In addition, though the model can be applied to make comparison among universities in a group, this study evaluates the effectiveness of a single university to demonstrate the model.

1.3 Terminology

The topic of the study is technology transfer from university to industry. In practice, the term "university technology transfer" is often used to refer to the activities for which the Technology Transfer Office is in charge of at a university, particularly licensing and technological start-ups. This conventional understanding of the term is also used in research although the scope of technology transfer has gone beyond technology licensing from universities to include other means such as research publications, conferences, training, etc. In fact many scholars point out that technology transfer from universities is not just about licensing but involves many other forms of knowledge transfer. Some researchers use the term knowledge transfer to study the subject, implying a broader sense of the activity. Though there are studies trying to differentiate between knowledge transfer and technology transfer from universities, no norm has been developed in the literature regarding how the terms should be used by researchers to reflect the true nature of the activity. More often than not, the terms technology transfer and knowledge transfer are used at the convenience of the researcher.

This study adopts the broader sense of knowledge transfer from universities to include the conventional technology transfer definition, yet it does not aim to solve this terminology problem in the literature. Instead a compromised term will be used which includes both knowledge transfer and technology transfer, “University Knowledge and Technology Transfer” (UKTT). This term may not be neat but we believe it appeals to the research community in the field. However, the term “University Technology Transfer” (UTT) is used in the literature review section to refer to what has been used in the literature. The term “Knowledge and Technology Transfer” emphasizes the broader scope of the research, while the term “Technology Transfer” helps readers relate to what is familiar to them.

CHAPTER 2: LITERATURE REVIEW

2.1 University Technology Transfer as a Research Field

University Technology Transfer (UTT) is not new, though it might have been represented in practice and research literature under different terms over different periods of time. The land-grant college system was born out of the passage of the Morrill Act of 1862, with agriculture methods and technologies among the first examples of active US university technology transfer in the 19th century. However it was not until the 1980s that the UTT gained momentum in practice as well as research since the passage of the Bayh-Dole Act.

To demonstrate, a quick bibliographic search done on Google Scholar search engine using the term university technology transfer as a key word to search for any related publications prior to 2010 shows the young age of the field relative to the other established management fields, but gaining significant momentum in recent years (Figure 1). There are several terms used in the literature to refer to the subject, for example university industry relations, university industry partnerships, university industry links / linkages, university technology / knowledge commercialization, university technology / knowledge transfer, university intellectual property commercialization, university entrepreneurship, university-industry interactions, university-industry collaborations, university technology transfer, university knowledge transfer, entrepreneurial university, academic research enterprises, university technology commercialization, and so on. In fact this plethora of terms makes it challenging to search the relevant papers in the literature and reflects the developing status of the research field. It also suggests the need for the research community to agree on common terminology for the subject. Figure 1 is the Google Scholar search for the term university technology transfer. The graph clearly shows the leap-frogging of research on the topic in recent years.

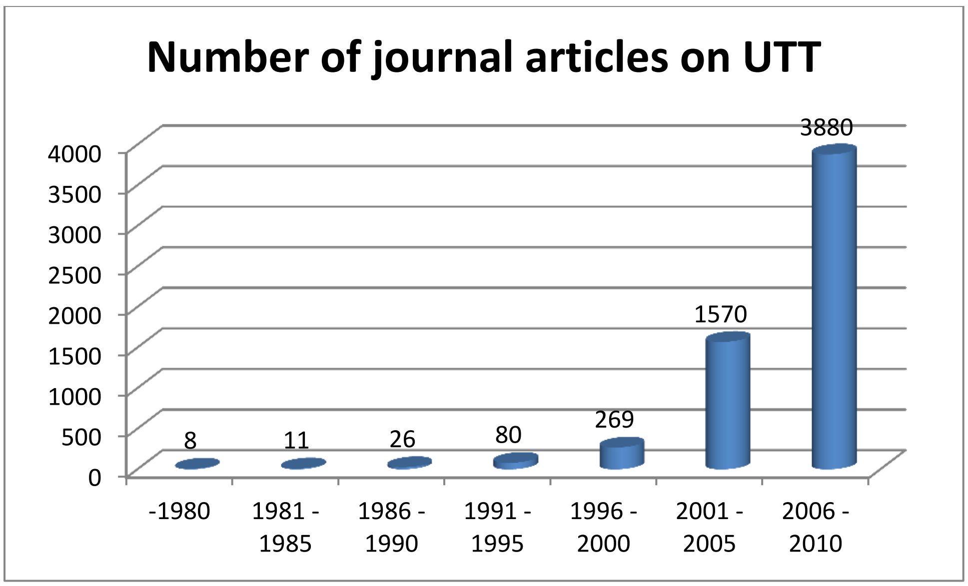


Figure 1: Number of UTT publications prior to 2010 from Google Scholar search engine.

According to Bremer, formal recognition of the university technology transfer concept had its origin in a report made to the President in 1945 by Vannevar Bush entitled “Science: The Endless Frontier”. The report recognized the value of university research as a vehicle for enhancing the economy by increasing the pool of knowledge for use by industry through the support of basic science by the federal government. Bremer also notes that long before the Vannevar Bush concept, but absent federal support in their research endeavors, the universities had been engaged in the transfer of the technology in many forms such as publications and consulting, although that specific term may not have been applied to their activities [1].

The literature also shows the development of UTT as an emerging research area. As early as 1984, Baldwin conducted a literature review of university industry relations. He studied nearly 100 publications, of which most were published during the 1979-1982 timeframe. This reflects the emerging phase of research on university technology transfer [2]. Poyago-Theotoky at al. conclude that we still know very little about the global impact of the rise of university-industry partnerships primarily because of data limitations. They project that more precise empirical evidence is likely to be available in the near future, given the trend towards greater scrutiny of public investments in R&D [3].

More recently, in 2007, Frank, Shanti and Lin published an exhaustive literature review of university entrepreneurship literature and found that most research in the field was published between 1981 and 2005, with the majority being published in more recent years. The Social Science Citation Index (SSCI) suggests that research on university entrepreneurship, which incorporates technology transfer, university licensing, science parks, incubators, spin-offs, TTOs, etc., appears to be moving at a faster rate in terms of citations garnered from mainstream journals than strategy research and other entrepreneurship research. However, the authors notice that most university entrepreneurship papers were published in specialty or niche journals, for instance, the *Journal of Business Venture*, as opposed to the leading management journals. This may reflect the embryonic stage in the life cycle of the field with its 25 years of development since the early 1980s, compared to the 50-year history of strategy research or 225-year history of economic research. Their study also shows that the field appears to be moving toward more theory-driven research, a trend that is reflective of the field's increasing maturity [4].

2.2 Major Issues in University Technology Transfer Research

This section aims to provide a review of the current literature on the critical issues investigated over the past decades concerning UTT. The main sources are international journals, books, and doctoral dissertations. Doctoral dissertations are excellent sources of literature reviews, yet are confined to a narrow topic of interest. This study includes recent journal articles that review university technology transfer as a research field. Previous literature reviews are also used to supplement the missing parts of the recent studies. It is interesting to see through the literature review how research topics have evolved over time.

One of the most recent and comprehensive literature reviews is the one by Rothaermel, Agung and Jiang in 2007 [4]. Their paper reviews 173 journal articles on university entrepreneurship literature in the period of 1981 – 2005, and produces several insightful findings. They observe that university entrepreneurship research, while an important and relevant topic, is a specialty within the broader entrepreneurship research community, reflecting the perspectives of a small group of stakeholders, i.e., university administrators, university faculty, and the technology recipient firms.

The authors develop a taxonomy of the literature categorized into four main themes: (1) entrepreneurial research university, (2) productivity of TTOs, (3) new firm creation, and (4) environmental context including networks of innovations. Entrepreneurial university research discusses the evolving mission of research universities and the organizational designs that inhibit or enhance the commercialization of university inventions. Another stream of research focuses on the technology transfer office (TTO) as a formal gateway between a university and industry. These studies view university entrepreneurship as a function of the productivity of their TTOs. Most measures of entrepreneurial activities are focused around commercial output. Research on new firm creation investigates university spin-offs as an entrepreneurial activity. Among instruments available for university entrepreneurship, spin-offs appear to be the most emphasized by the recent literature. Measurements of university spin-offs revolve around the quantity of new firms created, their performance, and their attributes. The research stream on environmental context including networks of innovation emphasizes that university entrepreneurship is a result of being embedded in networks of innovation, which in turn is influenced by the larger environment. (see Table 1).

Theme 1: Entrepreneurial Universities		
Internal factors	*Incentive system*	e.g. faculty, departments, TTO.
	Status	e.g. public/private, university prestige, departments (e.g. medical schools).
	Defined role & identity	e.g. boundaries, alignment of mission, basic vs. applied research.
	Culture	e.g. historical context, supportive.
	Policy	e.g. IP, conflict of interests, management support, changes, budget.
	Technology	e.g. feasibility, radicalness, productivity, contribution/focus.
	Faculty	e.g. motivation, business knowledge, disclosure, background, perception.
	Location	e.g. proximity to high-tech firms/industries.
	Intermediary agents	TTO, incubators.
	Experience	Institutional learning, experience.
External factors	*Industry conditions*	e.g. resources, opportunities, practices.
	Government policies	e.g. Bayh-Dole Act.
Theme 2: Productivity of TTOs		
TTO	*Structure*	e.g. reporting relationship, autonomy, age.
	Staff	e.g. admin propensity to license, admin ability and activity to market.
	System	e.g. incentives for TTO staff, resources, degree of self-sufficient, university vs. faculty objectives.
	Technology	e.g. stages.
	Methods	e.g. financial returns of licensing vs. equity, licensing strategy, effectiveness of patents, project evaluation.
	Faculty	e.g. propensity to disclose, shift of research focus, disclosures.
	University system	e.g. IP protection, culture, public/private, incentive system for faculty, R&D intensity, departments.
	Environmental factors	e.g. industry research support, state-level economic growth, R&D activity of local firms.
Theme 3: New Firm Creations		
	University system	e.g. policy, incubation models, research environment.
	Faculty	e.g. time and place, role, personality, department, quality, expectation.
	Investors	e.g. information gap, relationship, availability, JVC arrangement.
	TTO	e.g. presence, expectations, business capabilities, experience, age.
	Founders & Teams	e.g. experience, social capital, team development, scientific excellence.
	Technology	e.g. quantity, quality
	Networks	e.g. strength of ties, formality of ties/collaboration

	External conditions	e.g. industry R&D funding, federal funding, market opportunity, industry attractiveness
Theme 4: Environmental context		
	Innovation networks	e.g. coverage and scarcity of participants and research area, link with high educational institutes, collaboration with university scientists.
	Science parks	e.g. growth, added value, membership
	Incubators	e.g. types, services, added value, knowledge flow.
	Geography/location	e.g. proximity to university
	Science & faculty	e.g. type of research, role.

Table 1 : Taxonomy of university entrepreneurship literature, [4].

Rothaermel, at al.'s work [4] has made a significant contribution by providing a comprehensive taxonomy in university entrepreneurship literature. It is the most recent and extensive literature review covering the majority of the literature body on university technology commercialization, but it is geared toward new firm creation as the technology transfer outcome. New firm creation, though significant, is only one among several vehicles that universities employ to transfer knowledge and technology to society. As a result, their study inevitably leaves out many important topics of university technology transfer. Therefore, further search into other reviews makes the picture more complete. In other words, university entrepreneurship is one sub-set of university technology transfer literature.

Geisler and Rubenstein [5] also conducted a literature review as early as 1989 to identify major issues in university-industry relation research, including inherent differences in mission and objectives of the universities, differences in organizational structure and policies regarding technology transfer, and so on. Phan and Siegel presented a review of papers measuring the effectiveness of university technology licensing and business formation [6]. Drucker and Goldstein's review added research that assesses the impact of UTT on regional economic development [7]. Kim et al. identified researchers who aim to evaluate the effectiveness and efficiency of university technology transfer, and those investigating UTT transfer mechanisms [8].

2.3 Research on University's Mission in Relation to University Technology Transfer

This section reviews research on the on-going debate over the mission of universities. The question is what the main roles of a university are. Literature has shown an evolution of the mission of universities over the past several decades. The purpose of this review is to highlight the emphasis that universities now place on university technology transfer.

From a higher education perspective, Scott summarizes the evolution of university missions in Western countries as shown in Table 2 [9].

Pre-Nation-State Stage	
• Teaching mission	Emphasis on teaching (during the Middle Ages)
• Research mission	the Humboldtian model (during 19th and early 20th centuries)
Nation-state Stage	
• Nationalization mission	universities became national, serving the nation-states in Europe.
• Democratization mission	service to the individual of nation-state, first promoted as a mission in the formative US Colleges (1800s)
• Public Service mission	Service to the public of the nation-state, first arose as a mission of American higher education through the Morrill Acts of 1862 and 1890.
Globalization Stage	
• Internationalization mission	Internationalizing university missions of teaching, research, and public service on a global scale.

Table 2: Development of university mission in history [9]

From an innovation system viewpoint, Etzkowitz characterizes university responses to the changing environment in terms of two academic "revolutions". The first academic revolution, taking off in late 19th century, made research a university function in addition to the traditional task of teaching. A second academic revolution then transformed the university into a teaching, research and economic development enterprise. This transition initially took place with respect to industry at MIT, which was founded in 1862 as a "land grant" university. The entrepreneurial academic model was then transferred to Stanford, where it was introduced into the liberal arts university culture in the early and mid-20th century. Similar processes were underway elsewhere. An entrepreneurial academic format was currently being fashioned from a variety of historic university systems to meet the widespread need to generate new firms from knowledge resources in order to stimulate employment and productivity [10] [11] [12] (see Table 3).

Expansion of university mission		
Teaching	Research	Entrepreneurial
Preservation and dissemination of knowledge New missions generate conflict of interest controversies	First academic revolution Two missions: teaching and research	Second academic revolution Third mission: economic and social development; old missions continued

Table 3 : The evolution of a university's mission [10],[11] [12]

There are two opposing views in the literature regarding the fundamental question of what should be the main role of a university. The argument of the conservative opponents to UTT, from an economic point of view, is that academic technology transfer mechanisms may create unnecessary transaction costs by encapsulating knowledge in patents that might otherwise flow freely to industry. On the other hand, the UTT proponents argue about whether the knowledge would ever be efficiently transferred to industry without the series of mechanisms for identifying and enhancing the applicability of research findings [13]. Checkoway claims that whereas universities once were concerned with “education for citizenship” and “knowledge for society”, contemporary institutions have drifted away from their civic mission. He suggests that research universities adopt a strategy that promotes public understanding of their work as an essential part of their mission, recognizes an institutional responsibility for publicly useable knowledge, and develops a formal structure to sustain such uses. [14]. Pogayo-Theotoky et al. also point out the major drawbacks of an over-emphasis on university technology commercialization including the negative impacts on the culture of open science, the affect on the types of research questions addressed, the reduction in the quantity and quality of basic research, and the reduction in time spent by academics on teaching and research [3].

Moving from the traditional mission of universities to adapting a new mission has proved to be a difficult process. Argyres and Liebeskind show that the privatization and commercialization of biotechnology research conducted in US universities have been delayed and diminished in scope by parties seeking to hold up the tradition of open science practices, and thereby withstand the intellectual commons for the use of society at large [15].

The integration of new academic missions has always been accompanied by acute controversy at each phase. The first academic revolution made research a legitimate function of the university in the face of objections at the time, many of which still persist, that research activities were improperly taking professors away from their traditional role as educators. Likewise, the incorporation of entrepreneurial activities into a research university during the second revolution was often problematic and raised issues about the nature and purpose of the university [10]. In pursuing UTT, university staff spends too much time and effort on short term tasks which detract from the more fundamental long term goals. It undermines the trust in universities, the integrity of the scientist, the public appreciation of science, and the science itself [16]. Conflicting opinions over the university system's mission have been consistently identified across the literature as a key barrier to university entrepreneurship [4]. Baldini (2006) cites opposing views in the literature on university patenting and licensing activity that universities' entrepreneurial transformation has been criticized as a prelude to a substitution of basic research with a market driven one, thus endangering and fundamentally altering the societal role of public research [17].

Nevertheless, the transition from the teaching and research model into an entrepreneurial one seems inevitable and has been going on at research universities since the beginning of the 20th century. In a paper published in 2000, Etzkowitz and Leydesdorff introduced the Triple Helix model to explain the roles and interactions among the University, Industry, and the Government in innovation, development of new technology and knowledge transfer. They affirm that university research may function increasingly as a locus in the ''laboratory'' of such knowledge-intensive network transitions [13] [18]. Etzkowitz et al. review the movements of university mission in developed countries post World War II and confirm that a pattern of transformation toward an entrepreneurial university is emerging in the developed countries. The shift to encompass the "third mission" of economic development in addition to research and teaching arises from both the internal development of the university and external influences on academic structures associated with the emergence of "knowledge based" innovation. Entrepreneurial activities are undertaken with the objective of improving regional or national economic performance as well as the university's financial advantage and that of its faculty. More significantly, rather than being encapsulated within a special class of universities that have special interests in applied research or professional disciplines, the introduction of entrepreneurialism into the academic scene affects the educational and research missions of all of institutions of higher learning, to a greater or lesser degree [19]. Knowledge is now regarded not as a public good, but rather as "intellectual property", which is produced, accumulated, and traded like other goods and services in the Knowledge Society [20]. DeVol et al. assert the core mission of the world's leading research universities is education, discovery research and the dissemination of knowledge [21].

They maintain that technology transfer reflects the delicate balance of a university's wider culture and is, in fact, an important byproduct of its mission.

Lee conducted a survey in 1996 of approximately 1000 academics at research intensive universities regarding their attitude toward university technology transfer and found that US academics in the 1990s believed that they were more favorably disposed than in the 1980s toward closer university –industry collaboration. Most academics support the idea that their universities participate in local and regional economic development [22]. Etzkovitz (2004) describes the entrepreneurial university model in a set of inter-related propositions: Capitalization (of knowledge), Interdependence (with industry and government), Independence (as an institutional sphere), Hybridization (in organization), and Reflexivity (to changes) [11].

Gunasekara proposes a framework to examine the economic development role of universities which categorizes the role into two classifications: generative role and developmental role. The generative role involves the formation of knowledge capitalization mechanisms while developmental role involves entrepreneurial activities [23]. Rasmusen et al. explain that universities of science and technology undisputedly experience changes in their mission and activities toward technology commercialization. This is not new to many universities, but recent efforts from government authorities and university management have increased it. Two "waves" of commercialization can be identified. The first one happened in the early 1980s by the establishment of traditional science parks close to universities to increase collaboration with industry. The second wave accelerated around the second half of the 1990s, distinguished from the first one by a stronger focus on spin-offs and patenting/licensing rather than general industry collaboration, and an ever increasing perceived pressure when it comes to demonstrating the economic results of the university's activities [24].

Etzkowitz asserts that it is this "capitalization of knowledge" that is the heart of a new mission for the university, linking universities to users of knowledge more tightly and establishing the university as an economic actor in its own right [25]. Decter et al. also empirically conclude that the primary roles of teaching, research, and publication are the universal activities at universities, particularly in the US and UK, in which publication represents knowledge dissemination [26]. The entrepreneurial university model is also empirically tested and proved at leading universities in other countries [27] [28]. Todorovic et al. develop a scale named ENTRE-U to measure the entrepreneurial orientation of universities [29]. Friedman and Silberman find that one of the determinants of university technology transfer is a clear university mission in support of technology transfer [30].

Geuna and Muscio conclude that the scale of current university research and the increased reliance of knowledge in the production process have created strong incentives to develop a more efficient way of transferring the discoveries made in academia to the business world. Competition between research institutes and universities for public as well as private contracts has increased. As a result, universities are complementing their teaching and research activities with third stream activities oriented towards a direct socio-economic impact [31]. Mowery et al. say that the US higher education system has unique historical characteristics different from other developed countries in its lack of strong central governmental controls of policy, administration, or resources; its large scale; its dependence on local sources of political and financial support; and its strong interinstitutional competition for resources, faculty, and prestige. These structural characteristics of US higher education have created strong incentives for faculty and university administrators to develop strong links with industry [32].

2.4 Knowledge Transfer vs. Technology Transfer from Universities.

As stated earlier, the UTT research is a young and developing field in the literature, and it has not achieved a standardization of terminologies among researchers as compared to other established research fields. This causes confusion to any researcher who wants to draw a common understanding in the literature. For the interest of this research, this section will examine and discuss the distinction between and the interplay of two closely related concepts: university knowledge transfer (UKT) and university technology transfer (UTT). These two terms in some instances are used by researchers to refer to the same activity, yet in other instances they imply different scopes of activities. There is a need to clarify the meaning and usage of these two concepts. The following review attempts to answer an important question of the research: What is it a university doing - technology transfer, or knowledge transfer, or both?

One paper that investigates these two concepts in depth is that of Gopalakrishnan and Santoro. The authors define knowledge transfer activities as those involving educational programs, hiring new graduates, personnel exchange, and the level of participation in research papers between the university and the firm; whereas technology transfer activities are defined as those more directly involved in the development and commercialization of new technologies. They posit that technology transfer is a much narrower construct than knowledge transfer. Specifically, technology refers more to new tools, methodologies, processes, and products while knowledge embodies broader learning [33]. (Table 4)

Dimensions	Technology	Knowledge
Breath of construct	Narrower and more specific construct. Technology can be seen as an instrumentality or set of tools for changing the environment	Broader and more inclusive construct. Knowledge embodies underlying theories and principles related to cause and effect relationship
Observability	More tangible and precise	Less tangible and more amorphous
Overarching characteristic	More explicit and codified where learning can be taught and information is stored more in blueprints, databases, and manuals	More tacit where learning is by doing and information is stored more in peoples' heads
Management phase(s) of most consequence	Post-competitive phase of technological development (integral for the commercialization of ideas and inventions)	Pre and post competitive phases of technological development
Organizational learning	More reliance on controlled experiments, simulations, and pilot tests	More trial and error, wider use of gestalts
Nature of interactions	Inter and intra organizational interactions that mostly deal with organizational issues and how things work	Inter and intra organizational interactions that deal with strategic issues and why things work the way they do

Table 4: Key dimensions of technology and knowledge transfer [33]

Some researchers use the terms “knowledge transfer” and “technology transfer” interchangeably to refer to the same topic. Bozeman asserts that research on technology transfer is often drawn from communications research and involves movement of the intangible in combination with the tangible, because when a physical technology is transferred, intangible knowledge is also transferred [34]. Bremer states that long before the term university technology transfer was used universities were being engaged in technology transfer through publications in scientific journals, extension services, technical consultantships, and tangible products [1]. Baldwin uses the term UTT to define the movement of ideas and innovations from university laboratories and research centers to industry and on to the market place. This has traditionally taken a number of forms, including consultation to industry by faculty; hiring of new university graduates by industry; special courses and seminars for “retraining” and “upgrading” industrial scientists and engineers; and membership in professional societies [2].

Geuna and Muscio argue that while a focus on patents, licensing and spin-offs as mechanisms of knowledge transfer from universities to industry is understandable, it provides an incomplete picture. First, only a small fraction of the research conducted at universities can be codified in patents. Second, and equally important, the patenting channel accounts for only a small fraction of the overall knowledge transferred to industry [31]. Nelson observes after studying technology transfer at major research universities that there are two “myths” about the current technology transfer activity at American universities. One is that effective technology transfer almost always requires university patenting and licensing, or in other words, patenting and licensing greatly facilitate technology transfer. In many cases he has studied, putting the knowledge into the public domain through open publication and information dissemination was sufficient to spread it to the intended recipients. The second myth is that universities can expect a lot of money from their patenting and licensing activities. However, many universities are paying significantly more to run their patenting and licensing offices than they are receiving in license revenues [35]. In reality, research universities have been getting a very modest financial rate of return from their research investments. Many rely on just a few "blockbuster" patents to make big money [36].

Since knowledge is also embedded in legal instruments such as patents, many researchers use the term "knowledge transfer" to refer to the transfer mechanisms such as patent/licensing, spin-offs, etc. Link et al. use the term "knowledge transfer" as an informal university technology transfer channel in which the university researchers work directly with industry personnel in an effort to transfer or commercialize technology or applied research [37]. It is difficult to make a clear cut distinction between knowledge transfer and technology transfer concepts as both are intertwined in most cases. Arvanitis et al use the term "Knowledge and Technology Transfer" in their research [38]. Geuna and Muscio (2009) state that research collaborations, intellectual property rights and spin-offs are forms of knowledge transfer that are more formalized and have been institutionalized in recent years [31].

Conducting a survey of the TTOs at 12 top US research universities, Carlsson and Fridth conclude that technology transfer from universities to the commercial sector needs to be understood in its broader context. Since the primary purpose of a technology transfer program is for the university to assist its researchers in disseminating research results for the public good, success in this endeavor is only partially reflected in income generated for the university or the number of business start-ups. Other benefits include the creation of wealth, new jobs and new solutions to problems in society [39]. Knowledge and technology transfer from universities to industrial innovation move through many other channels in addition to patents and licensing. Indeed, patents and licenses are important sources of industrial innovation in only a few industries. Instead, other types of interaction, ranging from publications to the employment within industry of university trained scientists and engineers with experience at the frontiers of research, are of greater importance for innovation in many technology intensive and other industries [32]. Agrawal and Henderson found that only 10% of the knowledge is transferred from the research labs through patents, as estimated by researchers at MIT. That is in addition to the fact that only about 10-20% of faculty members file a patent as opposed to the 60% who publish in a given year during the 15-year period under investigation. The authors conclude that a focus on patenting or licensing statistics may significantly misrepresent the nature of the university's impact on the economy and that any comprehensive study of the issue must

Since the primary purpose of a technology transfer program is for the university to assist its researchers in disseminating research results for the public good, success in this endeavor is only partially reflected in income generated for the university or the number of business start-ups (Carlsson and Fridth, 2002)

include a focus on the other channels through which university knowledge is transferred to private firms [40].

In conclusion, some researchers use the term “technology transfer” to refer to an institutional activity that requires organizational structures and processes to move the research results to the market place such as patent and licensing or spin-offs, whereas others use “knowledge transfer” when investigating the more personal interactions between academic researchers and industry though there are overlaps between these two types of activities. Few “technology transfer” researchers mention informal channels such as conferences and consulting as transfer mechanisms but “knowledge transfer’ researchers often include patents, licensing, and spin-offs. This indicates that knowledge transfer is a broader concept and it incorporates technology transfer.

2.5 Transfer Mechanisms for University Research Outcomes

Geisler and Rubenstein conducted a literature review on university – industry relations to identify the transfer mechanisms used in the literature. The authors categorized those mechanisms into four groups: industrial extension services, procurement of services, cooperative research, and research parks. The results show that university-industry interaction may range from a one-shot transfer of information to a complex and longer relationship, as in a research park or a cooperative research center [5].

Agrawal reviewed the literature on university to industry knowledge transfer and identifies such knowledge transfer channels as publications, patents, consulting, informal meetings, recruiting, licensing, joint ventures, research contracts, and personal exchange

[41]. Agrawal and Henderson investigated knowledge transfer mechanisms among MIT researchers including patents and licenses, publications, consulting, conversations, cosupervising, recruiting/hiring, conferences, and research collaborations [40]. Cohen et al. found that public research both suggests new R&D projects and contributes to the completion of existing projects in industrial R&D. Their results also indicate that the key channels through which university research impacts industrial R&D include published papers and reports, public conferences and meetings, informal information exchange, and consulting [42].

Link, et al. group the technology transfer mechanisms into two categories: formal and informal. Formal TT mechanisms are the ones that embody or directly result in a legal instrument such as a patent, license or royalty agreement. An informal TT mechanism is the one facilitating the flow of technology through informal communication processes, such as technical assistance, consulting and collaborative research. Formal TT is focused on allocation of property rights and obligations, whereas in informal TT, property rights play a secondary role, if any, and obligations are normative rather than legal [37]. Brennenraedts et al. present different categories of industry-science relations and identify the different knowledge transfer channels preferably employed by different groups of university researchers in the Netherlands. They find that established faculty members tend to use more traditional academic channels such as supervising PhD students or publications, whereas part time members leverage on their networking channels [43]. (Table 5)

A: Publications	Scientific publications Co-publications Consulting of publications
B: Participation in conference, professional networks & boards	Participation in conferences Participation in fairs Exchange in professional organizations Participation in board of knowledge institutions Participation in government organizations
C: Mobility of people	Graduates Mobility from public knowledge institutes to industry Trainees Double appointments Temporary exchange of personnel
D: Other informal contacts/networks	Networks based on friendship Alumni societies Other boards
E: Cooperation in R&D	Joint R&D projects Presentation of research Supervision of a trainee or PhD student Financing of PhD research Sponsoring of research
F: Sharing of facilities	Shared laboratories Common use of machines Common location or building Purchase of prototypes
G: Cooperation in education	Contract education or training Retraining of employees Working students Influencing curriculum of university programs Providing scholarships Sponsoring of education
H: Contract research and advisement	Contract-based research Contract-based consultancy
I: IPR	Patent text Co-patenting Licenses of university-held patents Copyright and other forms of intellectual property
J: Spin-offs and entrepreneurship	Spin-offs Start-ups Incubators at universities Stimulating entrepreneurship

Table 5: Different categories and forms of industry-science relations (Brennenraedts, et al.) [43]

In a related research Bekkers et al. study 24 knowledge and technology transfer channels from university to industry in the Netherlands and conclude that the relative importance of these knowledge transfer channels are not affected by the sector of the industry, yet by the disciplinary origins, the characteristics of the underlying knowledge, the characteristics of researchers involved in producing and using this knowledge (individual characteristics), and the environment in which knowledge is produced and used (institutional characteristics) [44].

D'Este and Patel also study knowledge transfer mechanisms through which academic researchers in the UK interact with industry and factors that influence the researchers' engagement in a variety of interactions. They find that university researchers interact with industry using a wide variety of channels, and engage more frequently in the majority of the channels such as consultancy & contract research, joint research, or training as compared to patenting or spin-out activities [45].

Arvanitis et al. classify Knowledge and Technology Transfer (KTT) activities into groups such as informal, technical infrastructure, etc. and find that research and educational activity groups improve the innovation performance of firms in terms of sales of considerably modified products, and research activity group in terms of sales of new products [38].

Gripme and Hussinger state that most of the existing research has focused on formal university technology transfer mechanisms, i.e. those that embody or directly lead to a legal instrument such as a patent, license or royalty agreement. Only a few authors have investigated informal university technology transfer mechanisms which focus on non-contractual interactions of the agents involved. The authors define formal UTT mechanisms as including collaborative research, contract research, technology consulting, licensing and acquisition of university technologies, and informal UTT mechanisms as “non-contractual contacts between firms and universities and public research institutes”. Research suggests that formal and informal technology transfer may go well together in that informal contacts improve the quality of a formal relationship or that formal contracts are accompanied by an informal relation of mutual exchange on technology related aspects. Their research of more than 2000 German manufacturing firms confirms this complimentary relationship [46]. In a related and more recent study, Grimpe and Fier compare the informal university technology transfer in the US and Germany. They find similar behavior of faculty in both countries. Faculty quality based on patent applications rather than publications serves as a major predictor of informal transfer activities [47].

Rogers, et al. study the technology transfer from university based research centers with the case of the University of New Mexico. According to the authors, technology transfer from university-based research centers occurs through: (1) research publications, e.g. scientific journal articles, (2) the incorporation of research findings into university courses, (3) the employment of former graduate students and/or research staff by private companies and other organizations, and (4) establishing spin-offs [48]. Among them, high technology spin-offs are a very effective technology transfer mechanism as they represent a significant part of the total investment and create the most employment [49]. Feldman et al. discuss sponsored research, licenses, hiring of students, and spin-off firms as major mechanisms of UTT [50]. Lee and Win explore the different modes of technology transfer at university research centers in Singapore and conclude that among different technology transfer mechanisms, a joint R&D project is an efficient way to ensure high commitment of industry to increase the transferability to industry [51].

Perkmann and Walsh study the relationship aspect of university – industry links and argue that in the context of open and networked innovation, inter-organizational relationships between public research organizations and industry play an important role in driving the innovation process [52]

Ralm, Kirkland and Bozeman list the linkage mechanisms fostering University-Industry R&D collaboration and the facilitating organizational units [53]. (Table 6)

Linkage mechanisms:

- Faculty members consulting for firms
- Student jobs placement in firms
- Student internships, co-ops, or industrial fellowships
- Alumni requests for faculty assistance for firms
- The university offering professional short courses or research seminars of likely interest to company personnel
- Evening, weekend, or company site delivery of university classes
- University efforts to show case new technologies developed or faculty research interest and skills
- Social interaction between faculty and industry personnel
- Research groups organized as multi-discipline teams
- University sponsored technology transfer conferences, technology expositions, or shows
- Industry grants to departments or colleges (money or equipment)
- Corporate gifts or on-going support to the university
- Personnel and equipment sharing
- Follow-up expertise delivery by inventors to firms purchasing a licensed technology
- Technology champions
- Membership in technology transfer organizations.

• Participation in state or local government economic development programs • Redefinition of university/college/department missions to encourage applied research and development
Institutional infrastructure: • University Intellectual Property Offices • University-industry Research Centers • Research parks • Industrial extension services • Contract research groups • Industrial R&D consortia • Industrial offices of technology transfer

Table 6: Linkage mechanisms and institutional infrastructure fostering University-Industry R&D collaboration (*Ralm, Kirkland and Bozeman* [53]*)*

Kim et al. find major university technology transfer mechanisms discussed in the literature including patent, licensing, spin-offs, consulting, training, and exchange programs [54]. Markman et al. classify UTT modes into three approaches: internal approaches, quasi-internal approaches, and externalization approach [55].

Besides research that reviews a wide spectrum of UTT mechanisms, a large number of other studies examine in depth a particular mechanism or specific group of mechanisms. Jensen and Thursby analyze the characteristics of university technology licensing and find that a major part of university technology inventions licensed to industry are in the embryonic stage and thus need inventor cooperation in commercialization [56]. Baldini reviews the literature on university patenting and licensing activity since 1980 and concludes that the surge of university patents (after the Bayh-Dole Act) did not happen at the expense of their quality or the quality of research. They also point out that scientific excellence and technology transfer activities reinforce each other [17].

Thune examines the role of doctoral students as an interface between universities and industry in the literature. Doctoral students are highly important in university-industry relationships since they are significant producers of knowledge in collaborative research projects. They are an important channel for knowledge transfer between firms and universities and are vital in network configurations between firms and universities. Yet little is revealed in the literature about this important knowledge and technology transfer channel [57]. Mosey et al. investigate the Medici Fellowship Program at five universities in the UK as a technology transfer mechanism. The authors conclude that such fellowship programs, through the retraining of academics, may have positive impacts on the commercialization of research in terms of: (i) encouraging culture change within biomedical departments; (ii) enhancing the human and social capital of the fellows; and (iii) encouraging fellows to act as network bridges between the different networks involved in the commercialization process [58]. Gulbranson and Audretsch put forth that proof of concept centers can play an important role in accelerating the commercialization of university innovation given the gap of funding from venture capital in early technological development stages [59]. Bercovitz and Feldman include serendipity as an informal technology transfer mechanism that might be used to initiate a relationship, which subsequently develops through other formal mechanisms such as sponsored research, licensing, hiring of students, and spin-offs [60].

O'Shea et al. study the success factors of spinoff activities at MIT, a leading spinoff generator in the United States and conclude that efforts at transposing or replicating single elements of MIT's model may only have limited success due to the inter-related nature of the drivers of spinoff activities [61]. Lowe develops an econometric model to explain and provide propositions of the decision making behavior of a university inventor in starting a spinoff [62]. Shea et al. explore the relationship among the attributes of resources and capabilities, institutional, financial, commercial and human capital to university spinoff outcomes [63]. Djokovic and Souitaris also review the literature on spinouts from academic institutions and show that while early literature has been mainly atheoretical and focused on describing the phenomenon, a core group of recent studies were theory driven [64].

Saetre et al. conduct a comparative study on university spin-offs among Norway, the United States, and Sweden on four dimensions: university relations, government support mechanisms, industry relations, and equity funding. Their study finds important differences between the three countries, for instance US investors tend to invest more and at an earlier stage than their Scandinavian counterparts [65]. Nosella and Grimaldi analyze academic spin-offs in Italy. Their results show that the number of technology transfer officers, strong relationships with external organizations, and institutional supports have a significant influence on the formation of spin-offs [66].

Link and Scott consider university research parks an important infrastructural mechanism for the transfer of academic research findings, a source of knowledge spillovers, and a catalyst for national and regional economic growth [67]. In another paper, they study the spin-off companies from the university science parks[*] and find that parks associated with richer university research environments, or geographically closer to their university, or having a biotechnology focus tend to generate more spin-offs than others [68]. Siegel et al. allege that university science parks are a mechanism to stimulate technological spillovers [69]. Acworth describes a 6-component model of a knowledge integration community (KIC) at the Cambridge-MIT Institute that serves as a knowledge transfer center by bringing four institutional sectors (industry, government, research and education) through two binding mechanisms: knowledge exchange and the study of innovation in knowledge exchange [70].

Table 7 lists the knowledge and technology transfer means from universities discussed in previous research in the literature. The table highlights that some mechanisms are more common than others such as scientific publications, hiring of university graduates by industry, consulting services, licensing, spin-offs, etc. In other words, these common means are acknowledged mechanisms to transfer knowledge and technology from universities by the researchers.

UKTT means	References
Information transfer	[5] [17] [51]
University technology showcase	[53]
Scientific publications	[21] [38] [40] [41] [42] [43] [44] [48] [51]
Professional publications and reports	[44] [51]
Conferences	[38] [40] [42] [43] [44] [45] [51] [53]

[*] A university park is a cluster of technology-based organizations that is located on or near a university campus in order to benefit from the university's knowledge base and ongoing research. The university not only transfers knowledge but also expects to develop knowledge more effectively given the association with the tenants in the research park. (A.Link and J.Scott)

Workshops, classes	[5] [44] [53]
Knowledge access	[71]
Informal meetings/contacts	[38] [41] [42] [44]
Presentation of research	[43]
Industry sponsored meetings	[45]
Friendship networks	[43] [53]
Professional networks	[43] [44]
Alumni societies	[43] [44] [53]
Informal grouping of companies	[51]
Advisory boards	[43] [51]
TTO's activities	[44] [53] [55]
Membership in tech transfer organizations	[53]
University center or industrial liaison units	[51]
Industrial fellowships	[5] [58]
Graduate recruiting/hiring	[38] [40] [41] [43] [44] [48] [50] [53] [59]
Training for students	[5] [43]
Training and education of employees	[5] [38] [43] [44] [45] [51] [53] [54]
Common courses	[38]
Incorporation of research findings into courses	[48]
Providing scholarships	[43]
Sponsoring of education	[43]
Internships	[38] [43] [44] [53]
Co-supervising	[38] [40] [43] [45]
Doctoral students	[5] [17]
Personnel exchange	[41], [43] [44] [51] [53] [54]
Dual appointments	[43] [44]
Industry grants, gifts to university)	[5] [53]
Technical assistance	[37] [53]
Consulting services	[5] [37] [38] [41] [42] [43] [44] [45] [46] [53] [54]
Prototype development, fabrication, testing	[5] [43]
Industrial associates	[5]
Use of university facilities	[38]
Sharing of facilities	[38] [43] [44] [53]
Industry funded facilities	[45]
Patents	[17] [37] [40] [41] [43] [44] [54]
Co-patenting	[43]
Copyright	[43]
Licensing	[17] [37] [40] [41] [43] [44] [46] [50] [51] [54] [56] [59]
Follow-up consulting service to a license	[53]

Multi-discipline research groups	[53]
Cooperative research projects	[5], [37] [38] [40] [41] [43] [44] [45] [50] [51] [53] [59]
Cooperative research programs	[5] [44]
Research consortia / alliances	[5] [38] [53] [55]
Research parks, science parks, technology parks	[5] [51] [53] [55] [67] [69]
Joint ventures of R&D	[41] [51]
Spin-offs	[43] [44] [45] [48] [49] [50] [54] [55] [59] [61] [62] [63] [64] [65] [66] [68]
Incubators	[43] [55]
Stimulating entrepreneurship	[43]
Technology commercialization intermediaries	[55]
Proof of concept center	[59]
Participation in economic development programs	[53]
Serendipity	[59]
Knowledge Integration Community	[70]

Table 7: List of knowledge and technology transfer means used by universities in the literature

2.6 Research on Evaluation of University Technology Transfer Effectiveness

The first challenge any researcher faces in attempting to investigate this topic is to find a common understanding of how university technology transfer effectiveness is defined. One can find numerous studies in the literature that claim to address the issue of technology transfer effectiveness, yet instead they discuss another issue, or they approach the problem using different terminologies. To further complicate the matter, some researchers arbitrarily use those terminologies without a clear distinction of their meanings. For instance, Warren et al. state in their study: “In order to improve the efficiency of this transfer (i.e. the conversion of university research into economic growth), we have looked at the effectiveness of technology transfer activity in the USA.” without explaining how efficiency and effectiveness of the activity relate to each other

[72]. In fact, effectiveness evaluation and efficiency evaluation are two closely related, but separate problems. While efficiency studies are straightforward because they mainly measure the productivity of the technology transfer activity based on available quantitative data, effectiveness studies are often ambiguous as they touch on the qualitative aspect of the activity. In order to draw a boundary for this research, most technology transfer efficiency studies are excluded from this review, though some might be mentioned when appropriate.

The lack of agreement on the conceptualization of technology transfer effectiveness is one obstacle to its study. Past scholarly writing indicates a variety of definitions and measurements of technology transfer effectiveness [73]. In this section we will try to identify the research in the literature related to the issue of evaluating the effectiveness of university technology transfer and categorize it in a way that helps provide a clearer understanding of the literature.

An overall investigation of the literature reveals two main approaches that research on evaluation of university TT effectiveness have taken: (1) an innovation theory approach, and (2) an organizational theory approach. From an innovation diffusion perspective, Rogers defines *technology* as information that is put into use in order to accomplish some task; *technology transfer* is the application of information to use [74]. Thus *technology transfer effectiveness* is defined as the degree to which research-based information is moved successfully from one individual or organization to another [73]. The innovation diffusion theory approach stipulates that the effectiveness of technology transfer from university to industry is evaluated by how successfully research results are being moved or transferred from the source to the recipients*. This is a process-based approach in which researchers look to improve the success of the process. This group of papers can be found under similar subjects such as antecedents and determinants analysis, success factors analysis, performance assessment, impact analysis and so on. The studies found in the literature are predominantly in this category. With a different perspective, the organizational theory approach measures the effectiveness of university technology transfer based on how much the activity fulfills the host institution's mission and goals [73]. This approach is more judgmental than the process based approach and is rarely seen in the literature.

Innovation diffusion theory approach	*Organizational theory approach*
The degree to which research results are moved from the research institutions to external parties	The degree to which tech transfer activity helps a research institution achieve its institutional goals

Table 8: Two approaches to research on evaluation of UTT effectiveness

These two approaches can be applied at different levels of the institution: the TTO, the university, or the (local) government. At the TTO level the two approaches tend to converge since the objective of the TTO is more operational in nature, which is to

* Innovation diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system (Rogers [74])

facilitate the movement of intellectual properties from the university to industry. It is the day-to-day job of the TTO to successfully take the university's IP stock and put it out to market. At the government level, there is also a convergence of the two approaches which occurs at the macro level. The local governments are mainly concerned about the overall improvement of innovation in their regions while not directly engaged in specific technology activities. Research universities are positioned in the middle of this scale in the sense that a university carries out TT activities through its TTO to achieve its social goals. It is at the university level that one can see most clearly the difference between the two approaches, i.e. organizational process versus organizational objective perspectives.

Institutional level \ approach	Innovation diffusion theory	Organizational theory
TTO	*Successful movement of IP to industry*	
University	*Successful transfer of research results to community*	*Achievement of the university's third mission*
Government	*Improved innovation in the state*	

Table 9: Two main approaches to research on evaluation of UTT effectiveness at different institutional levels.

The following section reviews the literature on evaluation of university technology transfer effectiveness according to the above categorization. These papers are returned by the databases when key words including university technology transfer, effectiveness, and evaluations are used. Depending on their approach we can see how the researchers evaluate the effectiveness of the activity and what metrics are used. While a number of papers examine various aspects of the TTOs such as efficiency and productivity analysis, relatively few examine the effectiveness of the activity at this level. Thus priority will be given to those papers that directly address the question of effectiveness measurement over those that tackle the question from a remote angle.

Bozeman in his attempt to review and synthesize the voluminous literature on technology transfer suggests that technology effectiveness can take on a variety of forms and that technology transfer effectiveness can have several meanings, including market impacts, political impacts, and impacts on personnel and available resources. In this myriad of definitions, the term should be defined in light of the research domain and discipline being studied. In many instances, determining the meaning of technology transfer ‘‘effectiveness’’ proves daunting. Indeed, much of his analysis assumes multiple, sometimes conflicting, definitions of technology transfer effectiveness [34]. Link and Siegel claim to evaluate the impact of organizational incentives on the effectiveness of university/industry technology transfer while in fact their study measures the productivity of licensing activity of the TTO in terms of outputs over inputs [75], which is typically considered an efficiency study by other researchers.

Siegel et al. identify numerous impediments to effectiveness in university – industry technology transfer (UITT): cultural and informational barriers among the three key stakeholder types (university administrators, academics, and firms/entrepreneurs), TTO staffing and compensation practices, and inadequate rewards for faculty involvement in UITT [76]. They provide recommendations for improving the UITT process [77]. Phan and Siegel present a comprehensive literature review on the effectiveness of UTT to review and synthesize research on the antecedents and consequences of UTT. However they approach the issue from an entrepreneurial perspective and thus focus on research specifically pertaining to the formation of new firms based on university technologies, and the organizational factors that play a role in this process [78].

Some studies aim to assess the effectiveness of certain technology transfer mechanisms. Mian examines the university technology business incubator (UTBI) as a university's involvement in technology and business development support. The author proposes a UTBI performance assessment framework comprising three performance dimensions: (1) program sustainability and growth; (2) tenant firm's survival and growth; (3) contributions to the sponsoring university's mission. The third dimension essentially looks at student employment and training opportunities provided by the UTBI; faculty involvement as consultants/entrepreneurs; the extent of community, national, and international interest shown in the project; and any adverse impact on the university's primary mission of teaching and/or research [79]. Phillips examines the effectiveness of technology business incubators as a technology transfer mechanism. His study leads to a striking conclusion that technology business incubators have not had a high incidence of technology transfer despite the fact that many were established with that goal in mind [80].

Decter et al. identify gap funding and cultural differences as major barriers to effective UTT [26]. Warren et al. propose three new models for university technology transfer to improve the effectiveness of the activity as the authors argue there is no “one size fits all” approach [72]. However the paper does not provide a concrete definition of UTT effectiveness. Trune and Goslin carry out a profit/loss analysis of maintaining technology transfer programs at universities and find that approximately half of the programs appear to operate at a profit [81].

Rogers et al. assess the effectiveness of TTOs in terms of technology transfer and develop a composite measure of technology transfer effectiveness based on six steps in the technology transfer process (Figure 2). This measure equally weighs the six indicators of technology transfer effectiveness: (1) the number of invention disclosures, (2) the number of US patent applications files, (3) the number of technology licenses and options executed, (4) the number of technology licenses and options yielding income, (5) the number of start-up companies spun off from the university (based on a technology licensed by the university’s TTO), and (6) the total amount of technology licensing royalties earned per year. The authors adopt the organizational theory for TT effectiveness which is the degree to which an organization fulfills its objectives. Their research aims to answer the question, among others: “Can a measure of technology transfer effectiveness be developed for US research universities?”. Data used in the study were taken from AUTM. Expressed in different measurement units, the six TT effectiveness indicators are normalized by taking their standard scores (z-scores)*. The relative composite measure of technology transfer effectiveness for each university is obtained by averaging each university's z-scores for the six indicators. Thus research universities can be ranked on their TT effectiveness by ranking these composite values. The authors also suggest future research to look at data sources other than AUTM and NSF used in their study, and include the role of university administrators in the examination of university technology transfer effectiveness [49] [73].

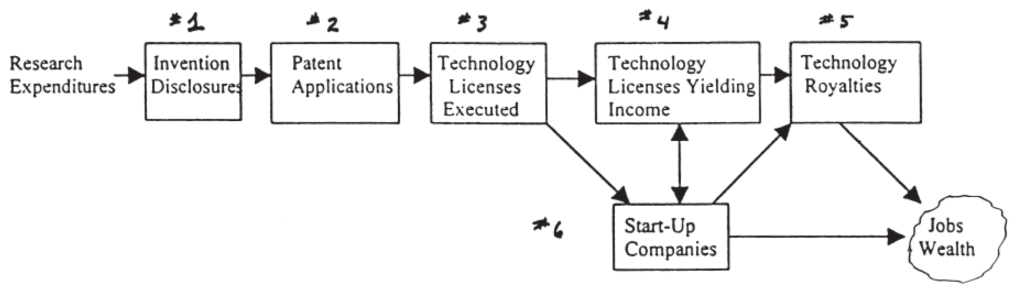


Figure 2: The process of technology transfer from a research university (Rogers et al.)

Adopting the organizational effectiveness definition in another paper, Rogers et al. examine the effectiveness of university based research centers of University of New Mexico. The authors identify eight dimensions of TT effectiveness that are shared among the research centers, including (1) technology transfer (mechanisms), (2) training and placing former graduate students (and staff) in outside employment, (3) total budget, (4) research productivity, measured in number of publications, (5) staff size, (6) length of existence (in years), (7) the director's role, and (8) the number of departments

* A z-score is calculated as the difference between an observation on some variable (for example, the average number of invention disclosures by a university) and the mean for that variable (the average number of innovation disclosures for all universities), divided by the standard deviation for the number of invention disclosures for all universities. In essence, a z-score, also called a standard score, expresses each observation in terms of standard deviation units from the mean.

represented in each research center. The authors rate each center on a 5-point scale (0-4) on these eight TT effectiveness dimensions using data from their personal interviews with the research centers and other materials, then the TT effectiveness score of each research center is obtained by summing the ratings of all eight TT effectiveness dimensions, averaging among the raters. The highest possible TT effectiveness score would be 32 [48].

In 2006 the Milken Institute issued a report on a global analysis of university biotechnology transfer and commercialization. The authors developed several indexes to allow comparison and rank individual universities among their peers on their performances of technology transfer and commercialization in biotechnology in three separate dimensions: publication, patent, and technology commercialization. The Publication Index measures the quantity and quality of published research of a university, the Patent Composite Index measures the quantity and quality of patents owned by a university. The Technology Transfer and Commercialization Index measures the performance of the university. The weights used in each Index are assigned subjectively by the researchers [21].

Index	Metric	Weight
Publications	1. Number of publications	0.4
	2. Activity	0.2
	3. Impact	0.4
Patent	*1.* Absolute number of patents	0.65
	2. Current Impact Index	0.15
	3. Science Linkage	0.1

	4. Technology Cycle Time	0.1
Technology Transfer and Commercialization	1. Patents Issued Score	0.15
	2. Licenses Executed Score	0.15
	3. Licensing Income Score	0.35
	4. Start-up Score	0.35

Table 10: Performance Evaluation Indexes of University Technology Transfer (*Milken Institute, 2006)*

Sorensen and Chambers argue that it is time to shift academic technology metrics away from the primary focus on measuring patents and money to a more balanced metric focused on the mission of the research institution, which is making access to knowledge available. A knowledge access metric is defined based on how well a TTO provides access to knowledge. An access metric augments conventional TT measures by tracking citation analysis, research exemptions, humanitarian use exceptions, alliance management, exclusivity shifting, capacity building in developing regions, open source business modeling and patent pooling or bundling for incremental or related technologies, where possible. The case of Johns Hopkins University is cited to exemplify this concept* [71]. Based on a literature review and their own experience in research and consulting, Geisler and Rubenstein propose a guideline for determining indicators for evaluating university-industry interactions [5]. They also give illustrative examples of these indicators when applied to the four types of university-industry interaction proposed in their paper. A summary of UTT mechanism indicators used in the literature is given in

* For Johns Hopkins University, conventional metrics analysis such as those used by AUTM attributes a rank outside of the top 25 global research institutions relative to technology transfer economic impact. By citation analysis, however, Johns Hopkins University places 7th globally in publication rankings and 3rd in patent rankings in biotechnology field [21] .

APPENDIX A. The list shows that conventional UKTT mechanisms such as publications, licensing, or incubators have been evaluated in detail whereas other less common mechanisms receive little or no attention at all in the research. Many UKTT mechanisms are mentioned in previous studies but they have not been evaluated with metrics. This observation indicates a need for future research of the less known UKTT mechanisms.

2.7 Discussion of the Literature

The above literature review has provided a picture of how university knowledge and technology transfer is implemented and evaluated. It spans a number of topics including the debate on the economic mission of research universities, the interplay between knowledge transfer and technology transfer, technology transfer mechanisms to UTT effectiveness evaluation. APPENDIX B summarizes selected papers reviewed in the earlier section together with a brief comment on each of the studies. These comments are given with respect to the intent of this research, i.e. evaluating university knowledge and technology transfer effectiveness in order to highlight the gaps in the literature.

Though there is still some skepticism most of the researchers have come to the agreement that research universities have taken on a third mission which is capitalizing on intellectual capital generated by research at universities in addition to the two traditional missions in the 19th century and first half of the 20th century. This "capitalization of knowledge" is being at the heart of a new mission for research universities (Ezkowitz,

[25]). Universities now promote knowledge and technology transfer to improve local business competitiveness, the regional economy and innovation as well as for financial recuperation from increasing research expenditures.

However as an emerging field of research in the 1980s this branch of management poses a dispersion of topics, approaches and terminologies taken by the researchers. There is no consensus among the research community with regard to what technology transfer, knowledge transfer, various transfer mechanisms, and so on are. There is a need to clarify the interplay between knowledge transfer and technology transfer as these two concepts often go hand in hand. When a physical technology is transferred, intangible knowledge is also transferred [34]. European researchers often use the term knowledge transfer to investigate a broad spectrum of the activities involved in transferring research results to industry, while their American counterparts tend to use the term technology transfer, which reflects a focus on patenting, licensing, spin-offs and the role of the TTOs at American universities. There is a concern about what the scope of technology transfer at universities in America should be. Should it be confined to what the TTO is institutionalized for or be more than just that? In fact many researchers have pointed out that a focus on patents, licensing and spinoffs provides an incomplete picture (Geuna and Muscio [31]). Gopalakrishnan and Santoro posit that technology transfer is a much narrower construct than knowledge transfer [33]. Few technology transfer studies include conferences and publications as transfer mechanisms while knowledge transfer research often incorporate patents, licensing, and spin-offs among many others. While the taxonomy of terms not yet available it is suggested that researchers should adopt a broader perspective when assessing the transfer of research outputs from universities to industry in particular and society in general.

Figure 3 depicts the knowledge and technology transfer from universities to society including industry. The process starts with the expenditures by universities on research every year. The researchers or faculty conduct research and come up with new findings and knowledge from the research which is then either patented or not. In fact, only a small fraction of the generated knowledge can be codified in patents [31], and not all researchers patent their inventions [40]. According to knowledge management theory, knowledge can be classified as either explicit and tacit [82]. Explicit knowledge has been or can be articulated, codified, and stored in certain media. By contrast, tacit knowledge is difficult to transfer from one person to another by means of written or spoken language. Thus only the explicit aspects of new knowledge generated from university research can be codified in the form of patents or publications[*].

Then only a small share of the total codifiable knowledge is filed for patents by the researchers (10% - 20% at MIT, [40]). Some tacit knowledge is codifiable, but most (also called sticky knowledge) is not and remains with the researchers. Tacit knowledge can only be transferred effectively by means of personal contacts such as consulting,

[*] A typical example is the Bessemer steel process. Bessemer sold a patent for his advanced steel making process and was sued by the purchasers who couldn't get it to work. In the end, Bessemer set up his own steel company because he knew how to do it, even though he could not convey it to his patent users. Bessemer's company became one of the largest in the world and changed the face of steel making. (source: wikipedia.org)

workshops, personal exchange, joint research, etc. Previous studies which are focused on the TTOs only take into account the patented portion of the total new knowledge generated by university research from the total research expenditures. As a result, they face a dilemma of underestimating the return on investment of university research as only the returns, often in monetary terms, from legal instruments (patents) are accounted for (ROI (1) in Figure 3). This explains why the ROIs of US university technology transfer reported in some research are strikingly low. For instance, The Johns Hopkins University, the top research spending university in the US, consistently receives licensing income of less than 2 percent of its research expenditures for many years[*], while it has been rated among leading universities in research impact [21]. The question here is where the rest of the university's research outputs go to besides those legal instruments, or how the total knowledge generated from research gets transferred from the university to society. Figure 3 illustrates the answer to this question. The portion of the knowledge generated which is not patented will be transferred to the society via several other channels, ranging from the basic activities such as provision of technological information to the interested parties to more personal interactive means such as consulting. Through these researcher-centric mechanisms, a significant portion of the new knowledge, often tacit in nature, can be effectively transferred to the users. Therefore any study that aims to evaluate UTT should incorporate the impact of the informal knowledge and technology transfer channels into the analysis. By adding the missing link - ROI(2) in Figure 3 – the large investments in university research can be better justified. Obviously this is not an easy task, but it

[*] In 2007, the university spent $ 1.1 billion in research expenditures and received $10, 260,00 of licensing income for the corresponding year. (source: AUTM report, 2007)

highlights the dilemma when only hard data such as research expenditures and licensing incomes are used to evaluate UTT.

In close relation to the knowledge vs. technology transfer problem, the transfer mechanisms or activities considered in the studies also vary greatly depending on the researcher's perspective – the narrow technology transfer perspective or the broad knowledge transfer perspective. Even among the knowledge transfer studies it can be seen that different papers introduce different sets of knowledge transfer activities. Again, the researcher community has not yet provided a common set of knowledge and technology transfer mechanisms. While technology transfer activities involve new tools, methodologies, processes, knowledge transfer activities often engage broader learning (Gopalakrishnan and Santoro). Other researchers, e.g. Link et al., classify transfer mechanisms into formal and informal mechanisms. Formal mechanisms are those directly resulting in a legal instrument such as a patent, license or royalty agreement. Informal mechanisms focus on non-contractual interactions of the agents involved.

> Only 10% of new knowledge is transferred from the research labs through patents, as estimated by researchers at MIT. That is in addition to the fact that only about 10-20% of faculty members file for patents as opposed to 60% publishing in a given year during the 15-year period under investigation (Agrawal and Henderson, 2002)

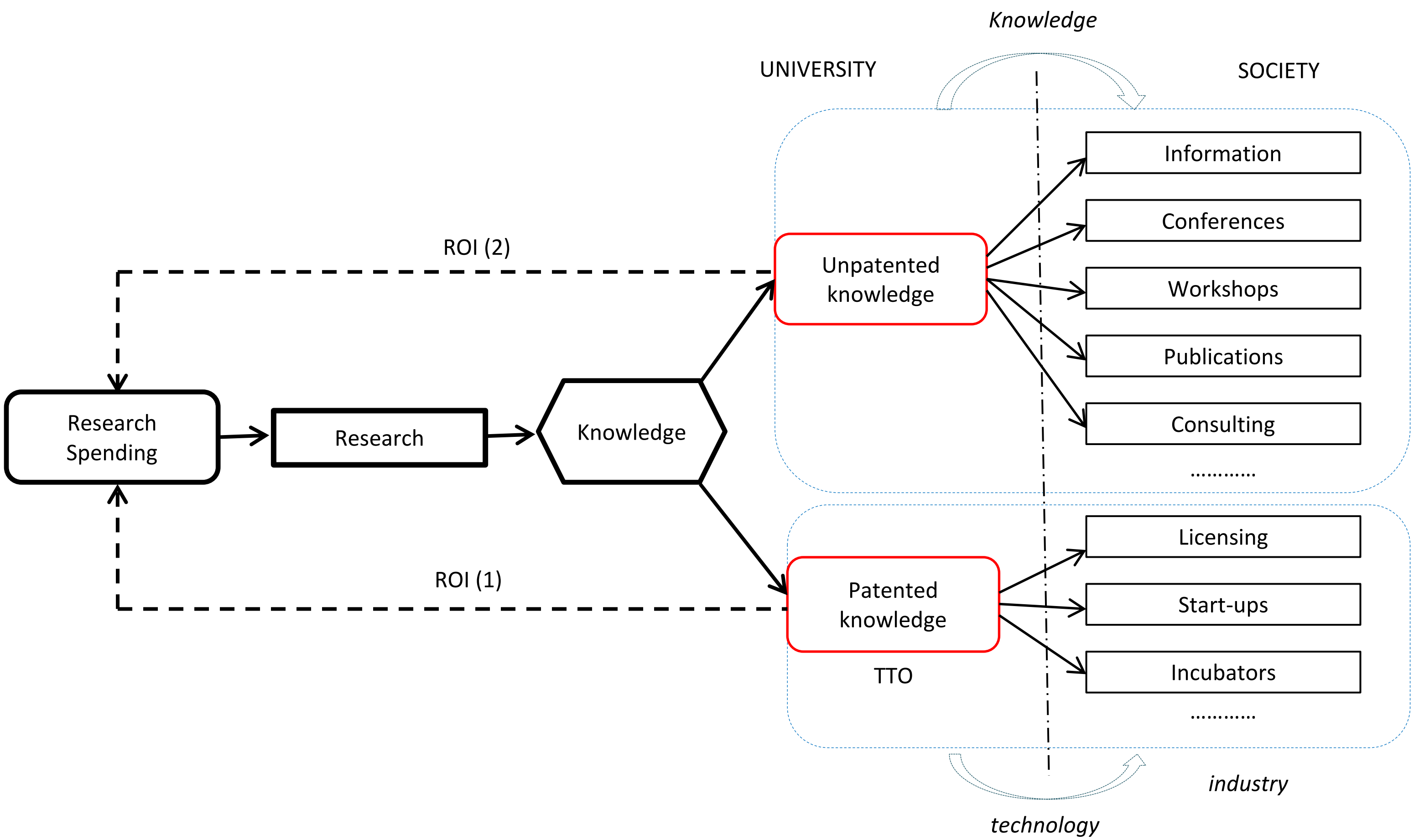


Figure 3: Knowledge and technology transfer from university to society

Most of the existing research has focused on formal TT mechanisms, while only a few studies have investigated informal mechanisms. In fact formal and informal technology transfers mutually reinforce each other (Grimpe and Hussinger). Agrawal concludes that non-patent channels are economically important, and there is a need for further research to specifically examine the nature of those transfer channels less studied in the literature [41].

Another observation from the literature review is that most studies do not pay attention to and focus on delineating the indicators or metrics of the technology transfer mechanisms to an adequate extent. Most papers only describe or discuss the mechanisms or investigate the impact of the mechanisms. An exception is the work by Geisler and Rubenstein, in which the authors propose a list of potential indicators for evaluating university industry interactions. However since the introduction of this study in 1989 its result has not been adopted in any other studies. Most studies employ common sense indicators such as number of patents, number of publications, amount of licensing income, etc. but this use is still not consistent across the studies. the Milken report by DeVol et al. is the only study that looks at the citations of research publications as indicators of the quality of publications used as a knowledge transfer mechanism. In short, there is a need for researchers to develop a comprehensive list of indicators and metrics of the knowledge and technology transfer mechanisms.

The striking finding from the literature review is that there are very few studies which directly address the issue of evaluating university technology transfer effectiveness. Some studies mention the effectiveness of UTT from a distant angle such as a literature review (Phan and Seigel) or propose models to improve the effectiveness of UTT (Warren et al). Some even claim that they address the UTT effectiveness problem while in fact they present a different issue (Link and Siegel). This is partly due to the fact that there is no universal definition of UTT effectiveness and thus researchers may use this term at their discretion. Many studies can be classified into the innovation or process based approach, i.e. they aim to investigate the effectiveness of the transfer process and its factors. Therefore these studies can take on subjects other than effectiveness evaluation, e.g. impact analysis, determinant analysis, success factor assessment, and so on. They share the same purpose which is to improve the success of the technology transfer process. In addition since they tackle the transfer process and its factors they tend to focus on the role of the TTO as the facilitator of the process.

Future research should look at data sources other than AUTM and NSF used in this study, and include the role of university administrators in the examination of university technology transfer effectiveness, (Rogers et al, 1999).

Only two studies found in the literature directly address and measure the effectiveness of UTT. One takes the TTO as the study object, the other research centers. Both of these studies were led by E.M. Rogers and define technology transfer effectiveness as the degree to which an organization fulfills its objectives through TT [*]. Interestingly, E. Rogers is the theorist of *diffusion of innovation* [74], yet he and his colleagues adopt the organizational effectiveness definition in their studies of UTT effectiveness, while the majority of researchers in the field adopt the process based on the innovation theory approach.

Nevertheless both studies of Rogers et al. have a major drawback. Both studies obtain TT effectiveness scores by using averaging method on the TT effectiveness indicators. In their 1999 paper [48], the data are derived from interviewing the research centers. In their 2000 paper [73], the indicators are based on the steps of the suggested TT process. The authors then use correlation analysis to justify the relationship between the indicators and the effectiveness score. In fact, the resulting effectiveness scores have no relation to the organization's objective as claimed by their definition since they are merely averaged scores of the indicators' values. The former paper has no upper limit for the effectiveness score while the latter set the experts' maximum ratings, which do not represents the university's objectives, the upper limit of the effectiveness score. Hence these studies can only rank the organizations on their TT effectiveness scores, but can make no conclusion about how effective each organization is relative to its own objective. The mismatch between the definition and the measurement of UTT effectiveness is the main shortcoming of these two studies. In addition the latter paper was restrained by the data available only from AUTM, and thus the effectiveness score was biased.

[*] Rogers et al (1999) [48]: see page 692 for definition.
Rogers et al (2000) [73]: see footnote 4 in his paper for definition.

In an attempt to make a distinction among the many related research problems found in the literature concerning evaluation of university technology transfer, this study presents a description of research topics that are different but often confused with each other, including process evaluation, performance evaluation, efficiency evaluation, and effectiveness evaluation. Many studies in the literature fail to recognize the differences among these concepts and thus they often confuse the terms. For instance a paper claiming to address the effectiveness problem of technology transfer may in fact simply examine the outputs or performance of the activity. This distinction is necessary for this study as well as future research in defining the focus of the research problem. This categorization also covers most problems concerning UTT evaluation in particular or technology transfer evaluation in general.

Research problem	Description
Process evaluation	The evaluation of the phases, stages, antecedents, determinants, etc. These are influential factors that help improve the success of the TT process
Performance evaluation	Evaluation of the outputs of TT activity.
Efficiency evaluation	Evaluation of how well the TT activity is performed, measured by the ratio between the outputs and inputs of the process.

Effectiveness evaluation	Evaluation of the degree to which TT activity is achieving the organization's desired result*.

Table 11: The distinction among the related topics in technology transfer evaluation

From the above discussion of the literature, some major gaps with respect to the research interest of this study are identified as follows:

Gap 1: There is no organizational mission-oriented study to evaluate UKTT effectiveness.

A large number of studies in the literature measure UTT effectiveness by an innovation diffusion, or process-based, approach. These studies aim to analyze and improve the UTT process, and they are often descriptive in nature. Some of them focus on process productivity while claiming to address the effectiveness of UTT. Only two studies by Rogers directly measure the UTT effectiveness and claim to adopt an organizational effectiveness definition. However both of them actually come up with TT effectiveness scores that do not relate to the organizational mission. In addition, one study by Rogers only examines TTOs; the other is targeted at university-based research centers. Thus there is a need to extend the group of organizational effectiveness studies for UTT which define UTT effectiveness as the degree to which the university's

* Definition of effectiveness: "Effectiveness is the degree to which something is successful in producing a desired result", (Oxford Dictionary).

mission is achieved through UTT activities.

Gap 2: There is no common set of mechanisms and metrics for UKTT research

It is easily seen in the literature that every UTT study uses a convenient set of TT mechanisms, mostly involving legal instruments such as patents, licensing, and spin-offs. As pointed out earlier, this narrow set of TT mechanisms may represent a biased view of university TT since legal TT instruments only constitute part of the knowledge transferred from a university to industry. Some studies introduce wider ranges of UTT means, yet these sets of UTT means are different from one study to another. In particular the two papers by Rogers only examine limited TT mechanisms, mostly involving legal instruments. Thus there is a need for a comprehensive set of transfer mechanisms which best represents the wide spectrum of UKTT and serves as a reference for future research in the field.

Gap 3: There is limited use of available research methods in previous studies

APPENDIX B shows that a large number of studies are explorative such as literature review, case studies, and discussion. This reflects the developing status of the UTT field. Another group of studies quantitatively examine the topic, albeit using simple research methods such as descriptive statistics, correlation analysis, etc. While a variety of research methods for technology management studies are available [83], only a few have been employed to study UTT effectiveness. This represents an opportunity for future research to apply other research methods because they can help solve different problems in the field. Particularly for organizational effectiveness analysis, a judgment quantification method should be applied as these studies often entail the subjective judgments of experts to measure the degree to which the organization's mission is achieved.

CHAPTER 3: RESEARCH OBJECTIVES, RESEARCH QUESTIONS, AND RESEARCH METHODOLOGY

3.1 Research Objectives

Having reviewed the literature on the topic of research and identified the gaps in the literature, this study aims to achieve the following objectives:

Objective 1: To evaluate organizational effectiveness of UKTT at the university level

As mentioned in Gap 1, most research on UKTT effectiveness looks at analyzing and improving the UKTT process without actually measuring the effectiveness of the work. Only two studies by Rogers adopt the organizational effectiveness definition and aim to measure the UKTT effectiveness by developing UKTT effectiveness scores. However both fail to conform to their definition of UKTT effectiveness. This study fills that gap by developing an organizational mission oriented approach to measure UKTT effectiveness. It aims to determine to what degree UKTT contributes to a university's mission. The study takes into consideration the entire spectrum of knowledge and technology transfer activities taking place across the university rather than being confined to the TTO or a similar unit in the university. This is to ensure the comprehensiveness and significance of the research.

Objective 2: To compile a common set of mechanisms for UKTT research

Gap 2 says that no previous study has offered a common set of mechanisms representing the entire range of UKTT activities. Each study in the literature presents a different compilation of UKTT mechanisms. Many only look at those means related to legal instruments such as patents. Thus the second objective of this study is to compile a comprehensive collection of various UKTT mechanisms which include both technology and knowledge transfer means. Together with this mechanism list the research also develops a set of metrics for each of the UKTT mechanisms in order to measure their performances. It is hoped that this comprehensive list of UKTT mechanisms with their metrics will serve as a reference for future research in the field of UKTT research.

Objective 3: To apply a new research method for UKTT effectiveness study.

This study resolves the weakness of previous studies in evaluating UKTT effectiveness, particularly the two by Rogers, by applying a novel research method that can determine the contribution of UKTT means or mechanisms to the overall mission of the organization. To measure the organizational effectiveness of UKTT, subjective judgments or ratings from experts who have in-depth knowledge and hands-on experience of the matter must be sought. Therefore the study develops a research model that utilizes a judgment quantification method to achieve a measure of the UKTT effectiveness. It is the first research in the field to demonstrate the contribution of each UKTT means to the overall effectiveness score. This novel approach also allows evaluating UKTT effectiveness of individual universities as well as comparing a group of universities.

3.2 Research Questions

This research achieves the above-stated objectives by resolving the following research questions:

With respect to Objective 1: To evaluate organizational effectiveness of UKTT at the university level

- Research question 1.1: "What are the definitions of UKTT and UKTT effectiveness?"
- Research question 1.2: "What are the mission and objectives of a research university with respect to knowledge and technology transfer?"
- Research question 1.3: "Who at the university are involved in knowledge and technology transfer to industry?"

With respect to Objective 2: To compile a common set of mechanisms for UKTT research

- Research question 2.1: "What are the knowledge and technology transfer mechanisms, including formal and informal means, from university to industry from both literature and practice ?"
- Research question 2.2 "What mechanisms are more representative and should be included in the comprehensive set of UKTT mechanisms?"
- Research question 2.3: "What are the clusters, if any, of the technology transfer mechanisms?"
- Research question 2.4: "What are the indicators and metrics used for each UKTT mechanism?"
- Research question 2.5: "How to measure the metrics of each UKTT mechanism?"
- Research question 2.6: "How to normalize different metrics of the UKTT mechanisms?"

With respect to Objective 3: To apply a proper research method for the UKTT effectiveness study.

- Research question 3.1: "What judgment quantification method is appropriate for this study?"
- Research question 3.2: "What is the tentative research model and what are its elements?"

- Research question 3.3: "What are the steps to develop the research model? "
- Research question 3.4: "How is the model validated?"
- Research question 3.5: " How are the model inputs obtained and processed? "
- Research question 3.6: "How are the results tested?"
- Research question 3.7: "What implications can be drawn from the results?"

These research questions are addressed in this study. The following section introduces the Hierarchical Decision Model and the accompanying judgment quantification method as an appropriate research method for the research.

3.3 Research Methodology

3.3.1 Introduction to Hierarchical Decision Model (HDM) and Analytic Hierarchy Process (AHP)

This study evaluates the effectiveness of UKTT from an organizational perspective, meaning that the effectiveness of UKTT activities is measured by the extent to which those activities fulfill the university's mission. This perspective lends itself more appropriately at the university level rather than the TTO level to ensure the comprehensiveness of the research. The definition of organizational effectiveness entails a measurement based on judgment of the involved parties since hard data are not as available as they are in the case of a process-based definition. This approach requires the selection and application of a judgment quanfication method which is capable of determining the contribution of each of the UKTT activities to the organization's mission. The decision theory suggests that HDM best suit the purpose of this study. This section presents the HDM in detail.

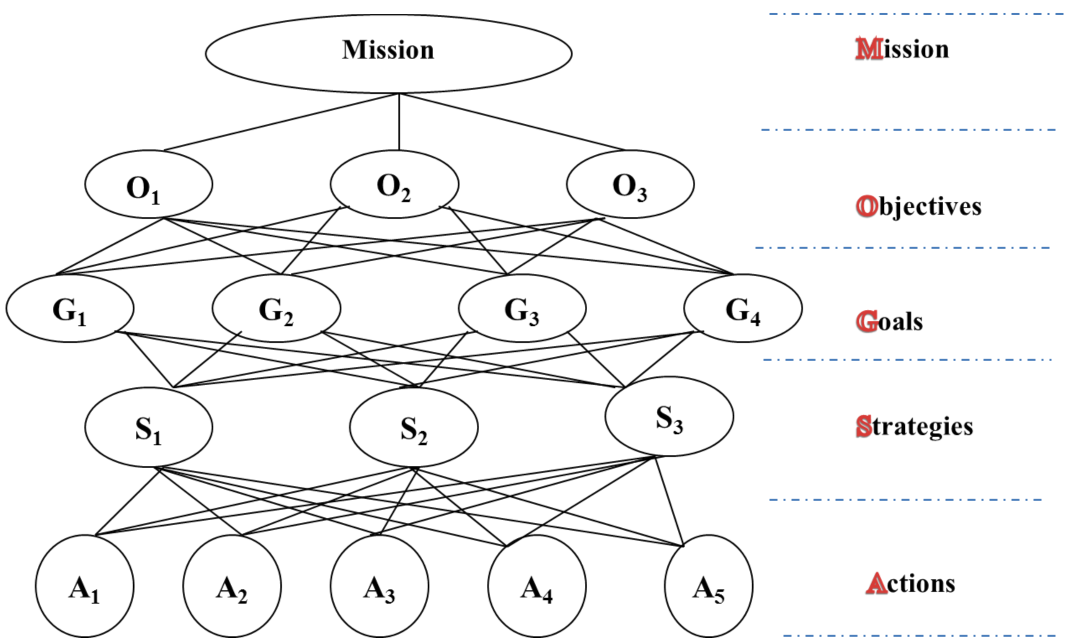


Figure 4: MOGSA as a Hierarchical Decision Model (Cleland, Kocaoglu)

The MOGSA model was first used by Cleland and Kocaoglu in 1981 [84]. It is a hierachical decision model consisting of five levels labeled Mission, Objectives, Goals, Strategies, and Actions, as shown in Figure 4. The Mission level represents the stated mission of the organization regarding the question of interest. Objectives are achievements that the organization should have in order to satisfy its mission. Goals are the targets to reach in order to fulfill the organization's objectives. Strategies are pathways the organization should follow in order to meet its goals. Finally actions indicate the activies that the organization should undertake in order to develop its strategies.

The essence of the MOGSA model is the Analytic Hierarchy Process (AHP), which was developed by Thomas Saaty in the 1970s [85]. It is a decision making method used for situations involving complex multivariable decision making problem where hard data for the decision making cannot be found readily. In other words AHP is a method to quantify judgments made by people who possess insightful knowledge and experience of the matter at hand. It is applied to prioritize the alternatives or actions based on the contribution values of the alternatives to the overall objective. The AHP incorporates judgments and personal values in logical way. It depends on imagination, experience, and knowledge to structure the hierarchy of a problem and on logic, intuition, and experience to provide judgments. It also provides a framework for group participation in decision making or problem solving. The AHP method has been developed since its introduction by several researchers and used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education.

Three principles of analytic thinking include [85]:

Structuring hierarchies: Humans have the ability to perceive things and ideas, to identify them, and to communicate what they observe. For detailed knowledge, our minds structure complex reality into its constituent parts, and these in turn into their parts, and so on hierarchically.

Setting priorities: Humans also have the ability to perceive relationships among the things they observe, to compare pairs of similar things against certain criteria, and to discriminate between both members of a pair by judging the intensity of their preference for one over the other. Then they synthesize their judgments – through imagination or, with the AHP, through a new logical process – and gain a better understanding of the entire system. In AHP a technique called pair-wise comparison is employed to derive the preferences of the judges.

Logical consistency: Humans have the ability to establish relationships among objects or ideas in such a way that they are coherent, i.e. they relate well to each other and their relations exhibit consistency. For example, if one judges honey to be five times sweeter than sugar, and sugar twice as sweet as molasses, then if that person is perfectly consistent he would judge honey to be ten times sweeter than molasses. Otherwise his judgments are not consistent. However human beings are inconsistent by nature, thus the AHP method allows judgmental inconsistence to a certain level, and methods have been developed to determine inconsistencies in the judgments.

In utilizing these principles, the AHP incorporates both the qualitative and the quantitative aspects of human thought: the qualitative to define the problem and its hierarchy and the quantitative to express judgments and preferences concisely. The process itself is designed to integrate these dual properties. It clearly shows that for better decision making the quantitative is basic to making sound decisions in complex situations where it is necessary to determine priorities and make tradeoffs. To calculate, we need a practical method of generating scales for measurement.

3.3.2 Inconsistency and Disagreement of the Expert Judgments

Two important parameters of the judgment quantification of an HDM are the consistency in judgments of an individual expert and the agreement among the judgment results of the expert group. Consistency indicates how consistent the expert is in providing quantification judgments in a pairwise comparison procedure. Agreement among the experts' judgments ensures the relative significance of the judgment results.

The consistency of an expert in this study is a measure of the variance among the relative values of the elements calculated in the n! orientations using the constant sum method given in the following formula

$$Inconsistency = (\frac{1}{n})\sum_{i=1}^{n}\sqrt{(\frac{1}{n!})\sum_{j=1}^{n!}(r_{sub_i} - r_{ij})_j^2}$$

The results of inconsistency calculations in this study are provided by the ©HDM software available at the Department of Engineering and Technology Management at Portland State University. An accepted rule is that the inconsistency index of an expert in a pairwise comparison procedure is not greater than 0.1.

The agreement among the experts' judgment is represented by a disagreement value of the expert group in a pairwise comparison procedure. The disagreement can be represented by an intra-class correlation coefficient, r_{ic}. The intra-class correlation compares the means among the judgments of the experts to show whether a pairwise comparison result might have a high or low disagreement. The intra-class correlation coefficient takes a value from $-1/(k-1) \leq r_{ic} \leq 1$. A coefficient of 1 means an absolute agreement among the experts, and a value of 0 or less indicates a significant disagreement. There is no proven threshold for an intra-class correlation to conclude whether the agreement test is accepted or not, albeit some source cites that a $r_{ic} > 0.7$ indicates a strong agreement among the judges [86].

In this study, to make an affirmative conclusion about whether or not the intra-class correlation coefficient, r_{ic} , indicates a significant agreement among the experts' judgments, a hypothesis testing procedure is used with the F-test, following the work by Shrout and Fleiss [87]. The Null Hypothesis for the F-test is that there is a significant disagreement among the experts' judgments, or $H_0 : r_{ic} = 0$. The F-value of a pairwise comparison procedure is calculated and compared against the F-critical value of the procedure to determine whether the Null Hypothesis can be rejected or not. If H_0 is rejected, we can conclude that there is not a significant disagreement in the experts' judgments. The F-values and F-critical values of the pairwise comparisons are provided readily by the ©HDM software.

If a pairwise comparison procedure is confirmed as having significant disagreement among the experts, we can identify whether or not there exists a dominant sub-group and/or outlier among the experts. A statistical procedure called hierarchy clustering analysis can help to implement this step. Then the "outliers" can be contacted again for possible modification of their judgments, or they set a case for a scenario analysis. Note that the "true" answer to the pairwise comparison results is unknown, so any judgment has a chance to prevail.

3.3.3 Desirability Values and Desirability Curves.

To evaluate the effectiveness of UKTT at universities, this study employs a concept called the desirability value set forth by D.F. Kocaoglu. The desirability value of an element represents how good or desirable the element is to the decision maker. In strategic decision making, decisions are often made not based on numerical values of the variables but the "goodness" or usefulness of those values. They are called desirability values of the variables. In this research, measuring the desirability values of the variables, i.e. UKTT mechanisms, is crucial for it measures the fulfillment of the variables with respect to the expectation of the university, i.e. the mission. The assumption behind desirability values is that the usefulness of an element to a decision maker does not always have a linear relationship with its numerical values. For example the "desirability" of 3 hamburgers for a person might not be 3 times as high as is 1 hamburger. Put in the context of this study, a total of 10 consulting contracts may not be two times as desirable by the university as 5 consulting contracts in terms of technology transfer. Therefore all the actual measurements of the metrics in the study are converted into desirability values by using the desirability curves. The use of desirability values for all the metrics also normalizes the different units of the metrics in the model, enabling the obtainment of a Technology Transfer Effectiveness Index. The desirability value of a metric is determined by developing a desirability curve for it and takes any value in the [0,100] range. That means the lowest measurement of the metric indicates a minimum desirability value of zero, and the highest possible measurement of the metrics represents the maximum desirability value of 100 points. Figure 5 depicts examples of desirability curves.

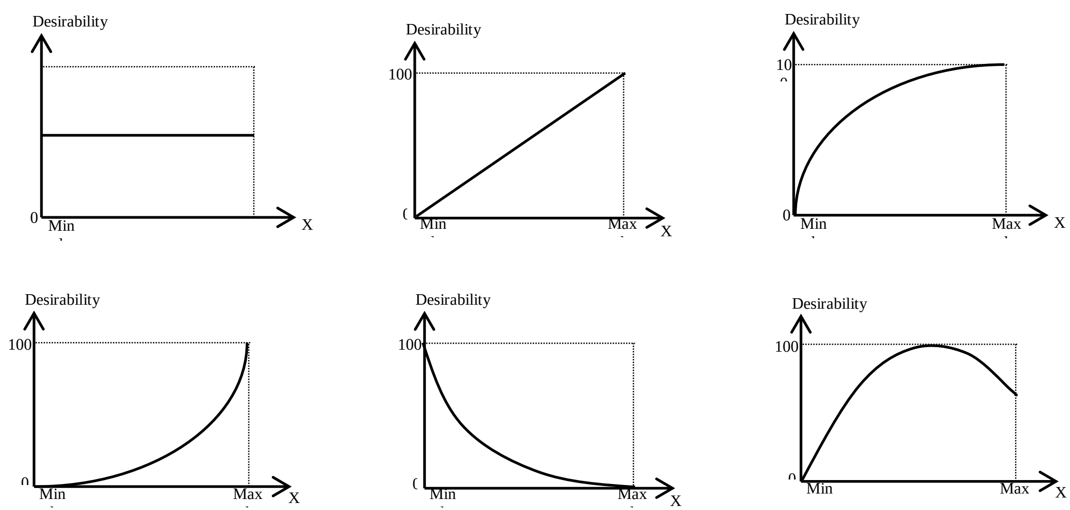


Figure 5: Examples of desirability curves

The experts responsible for judging the mechanisms and indicators help develop the desirability curves for each of the metrics. A research instrument is sent to the expert group members asking them to specify the desirability values corresponding to the values of the mechanism metrics. The desirability curves are used to determine the input values for the model when applied to a university.

3.3.4 Validation of the Hierarchical Decision Model

A developed research model should meet the requirements on the following tests of validity:

- construct validity
- content validity
- criterion-related validity

The purpose of these evaluations is to show the extent to which the model represents the conditions and phenomena it is designed to study. These tests apply to the research model and its measurement instruments. Only when these criteria are met will the research model and its measurement instruments be ready to use. The difficulty in meeting these tests is that usually one does not know what the true values are. Therefore , the validity of a model is always estimated, not proven ([88],p76).

Construct validity

Construct validity of an HDM model includes the validity of its elements. The construct validity of an element is the degree to which it relates to expectations formed from theory. A hypothetical construct is a measure which is not directly observable but is inferred from other variables. In many instances, the researchers want to measure or infer the presence of abstract characteristics for which no empirical validation seems possible ([88],p81). The purpose of construct validity is to ascertain if the measure of the variable of interest (which is not directly observable) can be assumed to be an accepted measure ([89], p151). In attempting to evaluate construct validity, we consider the theory and literature that discuss the construct to see how it is defined and measured. Once assured that the construct is meaningful in a theoretical sense, we can be certain that the variable used in the model is an accepted construct and we are going to measure what we want to measure. In this study, the major construct that is measured is the effectiveness of university knowledge and technology transfer.

Content validity

The content validity of a research model is the extent to which it provides adequate coverage of the topic under study. The content validity test assesses the degree to which the elements used in the model are a representative sample of all possible elements which the variable being measured is supposed to include. Determination of content validity is judgmental and can be approached in several ways. First, the designer may determine it through a careful definition of the topic of concern, the items to be scaled, and the scales to be used. A second way to determine content validity is to use a panel of persons to judge how well the instrument meets the standards ([89], p149).

Criterion-related validity

This form of validity reflects the success of the model used for prediction or estimation. A researcher may want to predict an outcome or estimate the existence of a current behavior or condition. This is *predictive and concurrent validity,* respectively. They differ only in a time perspective. The difficulty with estimating criterion-related validity is while the criterion may be conceptually clear, it might be unavailable. Consider the problem of estimating family income. There clearly is a true income for every family, however we may find it difficult to secure this figure. In the HDM of this study, the true relative importance values of the elements are unknown, and can only be estimated through judgmental quantification processes. As a result, the model results need to be verified so that they can actually represent the true UKTT effectiveness of a university.

Validity	What is measured	Usual methods
Construct	The degree to which a measure relates to expectations formed from theory for hypothetical construct	Judgmental Correlation of proposed test with established one Convergent-discriminant techniques Factor analysis Multitrait-multimethod analysis
Content	Degree to which the content of the items adequately represents the universe of all relevant items under study	Judgmental.
Criterion-related	Degree to which the criterion can capture the true value of the variable	Judgmental. Correlation
Concurrent	Description of the present; criterion data is available at the same time as predictor scores	
Predictive	Prediction of the future; criterion is measured after the passage of time	

Table 12: Summary of evaluation tests, ([89], p152).

3.3.5 Selection of Experts.

It is critical that the right experts are employed to ensure the accuracy and reliability of the results. The experts selected should possess the expertise that is relevant to the subject. Different criteria have been proposed by various scholars in choosing the right experts for HDM. Some scholars provide guidance for the candidates to rate themselves to see if they qualify as an expert on the subject [90]. Kocaoglu puts forward fives principles to select members of an expert panel as follows:

1. *In-depth knowledge.* The experts should have the expertise appropriate to the question under investigation. They have substantive knowledge and experience of the problem to be able to make accurate pair-wise comparisons.

2. *Balanced biases.* It is likely that individual members in the panel are inclined toward certain elements in the model so that they give more favorable judgments to those elements. This bias may stem from their own work experience or personal interpretation of the question. For instance an expert who is more familiar with technology licensing than business start-ups will likely put more weight toward licensing than the other. Thus, it is essential that these individual biases are balanced among the panel members.

3. *Balanced viewpoints.* Similar to individual biases, different viewpoints of the experts may influence their comparison results. For instance, an expert coming from a pure

science research university may have a different viewpoint about the objectives of UKTT than that of an expert coming from a technology commercialization oriented university. Again, the different viewpoints of the experts in a panel need to be offset.

4. *Avoiding silent by-standers:* In a group meeting, some members may maintain a go-with-the-flow attitude or avoid giving their opinions just to alleviate the conflicts among the group members. It is necessary to solicit all experts' personal ideas so that their inputs contribute to the improvement of the results.

5. *Avoiding domination by loudness.* In a meeting session, it is important to prevent any individual member to impose his or her own views and judgments on others. Disagreements should be addressed and even minor ideas should not be ignored.

The next question is "How can we identify the appropriate experts?". There are a number of methods to find the experts to be the panelists. Among them, three common approaches are used to make a list of the panel members as follows.

❖ *Use of personal connections*. This is a convenient and common way to create the list of experts. The researcher invites his or her acquaintances who are believed to have sufficient knowledge of the subject to participate in the expert panel. This method is useful in circumstances where resources and time are limited. The advantage of the method is time and effort efficiency, but the disadvantage is the experts might not be representative of the field.

- *Snowball sampling*. It is a technique where known experts recommend potential experts from among their acquaintances or networks. Thus, as more experts are recruited, the group grows like a snowball until enough experts are identified. This method is common among the researcher networks where one researcher often knows of other prominent figures in the field.

- *Use of social network analysis*. This method is an emerging technique in identifying prominent actors from large database. The researcher network can be considered a social network where one researcher usually cites others' papers in his or her own paper. In other words the researchers are inter-connected through the citations in their studies. A social network analysis technique can be used to analyze these citations to reveal the central points in the network, i.e. those researchers with more citations by others. The central researchers can be considered representative of the field, thus identified as expert panel members. The social network analysis process usually starts with generating a large database of the papers and their citations on the subject under investigation. This task can be done using a scientific research database such as Compendex, Science Direct, Web of Science, etc. Then a social network analysis tool such as UCINet, Social Network Visualizer, Pajek, Publish or Perish, HistCite, NetDraw, etc. is run to graphically map the network. The map visually and statistically points out those central points which are most connected by others in the network. This method is most comprehensive in identifying the best experts, however the entire process can be time and effort consuming in generating the databases needed, and the experts identified might not be cooperative due to the lack of personal connections.

3.4 Research Process

3.4.1 Research Flowchart.

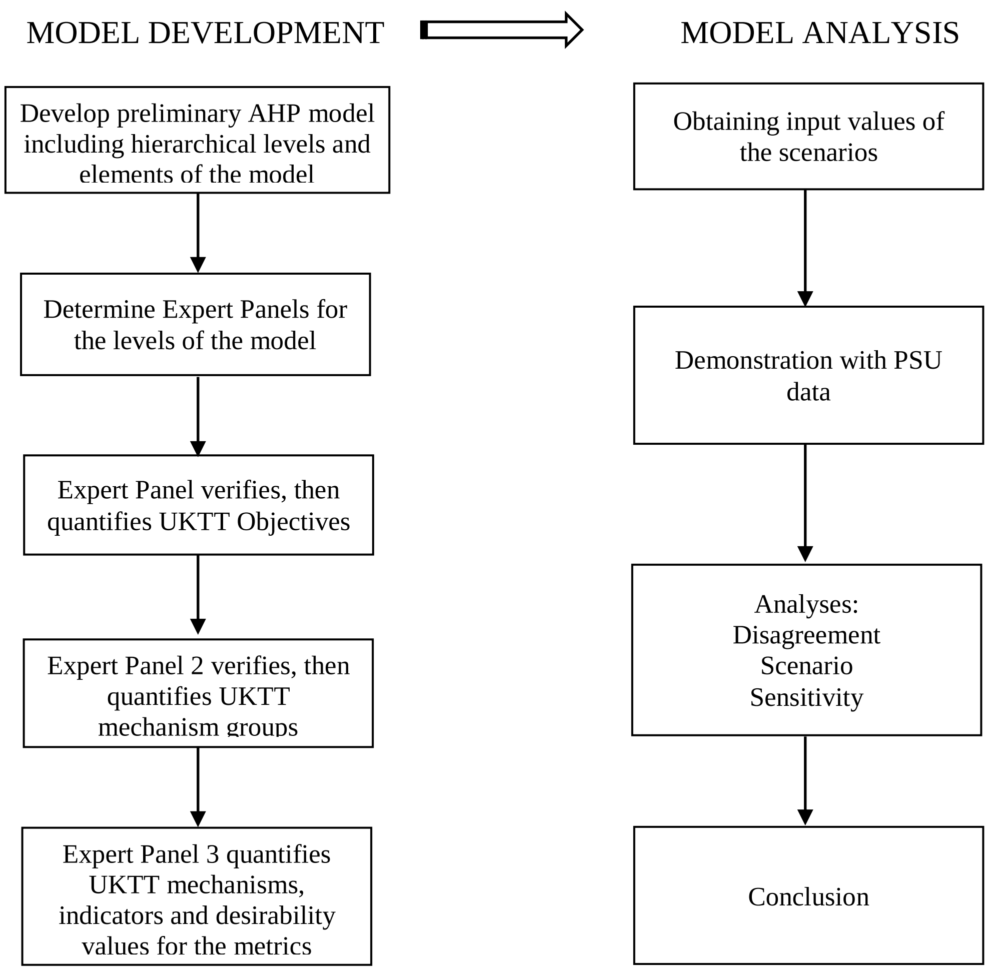


Figure 6: Research flowchart.

3.4.2 Metric Normalization.

Inputs for the model are the values of the mechanism metrics obtained from the university(ies) of investigation in a given year. However metrics have to be defined in such a way that their values are unaffected by the individual university's peculiarity. The reason is that the characteristics of a university, specifically size, have a bias effect on the measurement values of the metrics. For instance a university with 1000 researchers will likely have much greater values for the metrics as opposed to a much smaller university. Since the effectiveness of UKTT at a university is defined in this study as the extent to which the university achieves its mission, size or any other differentiating factors should not affect the result of how much the university achieves its mission. A small university may be well more effective in technology transfer than a larger counterpart, regardless of its size. This definition of the metrics also allows the comparison of UKTT Effectiveness among a group of universities. The data can be normalized based on many common factors such as the amount of researchers, research expenditure, number of licensing FTEs, etc. In this study the metrics will be normalized by the number of researchers (faculty members) in Science, Technology, Engineering, and Medical schools. However not all metrics can be, or should be, normalized by the number of researchers as some resulted input values will be out of scale. For instance the number of research parks if divided by the number of faculty members will be reduced drastically. Therefore the metrics are defined with normalization where adequate. More importantly the metrics should be clear and easy for the experts to perceive when giving judgments of the desirability values. For instance it is not as easy for the experts to judge "the number of new technology licenses per researcher in a given year" as just 'the number of new technology licenses in a given year".

3.4.3 Application of the HDM

3.4.3.1 Application 1: Evaluation of UKTT Effectiveness of a University.

The first and primary use of this study is to evaluate the effectiveness of knowledge and technology transfer at a university from an organizational effectiveness perspective. That is to determine how much all UKTT mechanisms carried out at the host university help it achieve its mission in technology transfer. This achievement is measured by a UKTT Effectiveness Index which takes a value from 0 to 100. An index of zero indicates a total absence or ineffectiveness of UKTT at the university while 100 represents an absolute effectiveness.

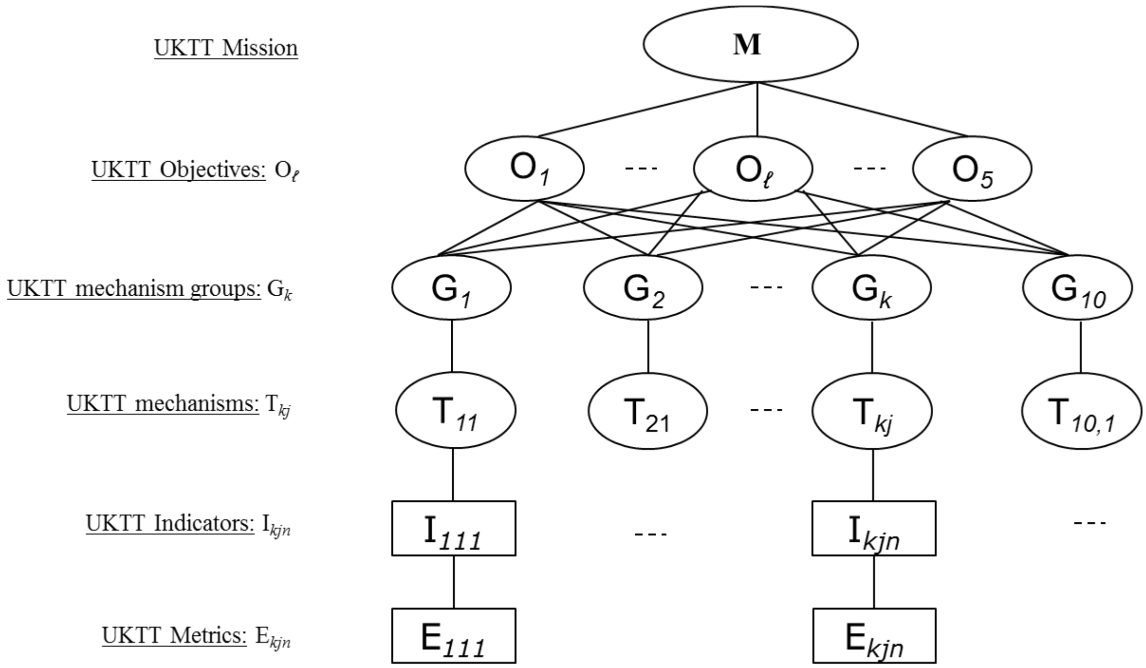


Figure 7: HDM with notations

We use the following notations and scripts for the elements in the model:

∗ Mission: M

∗ Objective: O

O_ℓ : Objective ℓ with $\ell = 1,.., L$

L : number of Objectives

o_ℓ : contribution of objective O_ℓ to the mission.

∗ UKTT mechanism Group: G

G_k : TT Mechanism Group k with $k = 1,\ldots,K$

K: number of TT Mechanism Groups

$g_{k\ell}$: contribution of group G_k to objective O_ℓ.

g_k : contribution of group G_k to the mission.

* UKTT Mechanism: T

  T_{kj} : TT Mechanism j in Group k with j = 1,…,J.

  J: number of TT mechanisms in Group k.

t_{kj} : contribution of mechanism T_{kj} to group G_k.

τ_{kj} : contribution of mechanism T_{kj} to the mission.

* Indicator: I

  I_{kjn}: indicator i of mechanism T_{kj} with n = 1,…,N

  N: number of indicators of TT Mechanism j in Group k.

i_{kjn} : contribution of indicator I_{kjn} to mechanism T_{kj}

$d(I_{kjn})$: desirability of indicator I_{kjn}

* Metric: E

  E_{kjn}: Metric of indicator I_{kjn}

  $V(E_{kjn})$: actual value of metric E_{kjn}

* Desirability value: D

  $D(E_{kjn})$: desirability value of Metric E_{kjn}

Note that there is one metric corresponding to one indicator. Thus:

$$D(I_{kjn}) = D(E_{kjn})$$

The computational process to determine the UKTT Effectiveness Index of a university is as follows:

Step 1: Determine the contributions of UKTT mechanism groups and UKTT mechanisms to the Mission

The contribution of the UKTT mechanism group G_k to the Mission is calculated by the following formula:

$$g_k = \sum_{\ell=1}^{L} g_{k\ell} \; x \; o_\ell \qquad \text{(Equation 1)}$$

And the contribution of the mechanism T_{kj} to the Mission is:

$$\tau_{kj} = t_{kj} \; x \; g_k \qquad \text{(Equation 2)}$$

Where t_{kj} is the contribution of mechanism T_{kj} to the Mechanism Group G_k

Step 2: Obtain the actual measurements of the UKTT mechanism metrics, $V(E_{kjn})$.

Step 3: Develop desirability curves and determine desirability values of the mechanism indicators $D(I_{kjn})$ *and metric* $D(E_{kjn})$.

Using the desirability curve developed for each of the metrics, from the actual value (measurement) of the metric, $V(E_{kjn})$, on the horizontal axis, derive the desirability value of the metric, $D(E_{kjn})$, on the vertical axis.

Since a metric is used to measure an indicator, we have $D(I_{kjn}) = D(E_{kjn})$

Step 4: Determine the Performance value of UKTT mechanisms, P(Tkj).

The Performance value of the UKTT mechanism T_{kj} is calculated from the desirability values and contribution values of its indicators, i_{kjn} , to the mechanism. The result indicates the performance level of the UKTT mechanism T_{kj} at the university.

$$\mathrm{P}(\mathrm{T}_{kj}) = \sum_{n=1}^{N} D(I_{kjn})\ x\ i_{kjn} \qquad \text{(Equation 3)}$$

where $D(I_{kjn})$ is the desirability value of the indicator I_{kjn}

and i_{kjn} is the contribution of the indicator I_{kjn} to mechanism T_{kj}

In addition, the Performance value of a UKTT Mechanism Group can also be determined.

$$\mathrm{P}(\mathrm{G}_k) = \sum_{j=1}^{J} P(T_{kj})\ x\ t_{kj} = \sum_{j=1}^{J}\sum_{n=1}^{N} D(I_{kjn})\ x\ i_{kjn}\ x\ t_{kj} \qquad \text{(Equation 4)}$$

Where $P(T_{kj})$ is the performance value of UKTT Mechanism T_{kj}

t_{kj} is the contribution value of UKTT Mechanism T_{kj} to its Group G_k

Step 6: Determine the UKTT Effectiveness Index for the university, UKTTEI.

The UKTT Effectiveness Index of the university is defined by the performance level of all the UKTT mechanisms carried out at the university with respect to its mission. Thus UKTTEI is determined by the performance values and the contribution values to the university mission of the UKTT mechanisms.

$$\boxed{0 \leq \mathrm{UKTTEI} = \sum_{k,j}^{K,L} \tau_{kj}\ x\ \ \mathrm{P}(\mathrm{T}_{kj}) \ \leq\ 100} \qquad \text{(Equation 5)}$$

where τ_{kj} is the contribution value of Mechanism T_{kj} to the Mission

and $\mathrm{P}(\mathrm{T}_{kj})$ is the performance value of Mechanism T_{kj}

The UKTT Effectiveness Index of the university under evaluation indicates the performance level of the university in knowledge and technology transfer with respect to its expectation, i.e. the university's mission. In other words, the UKTTEI indicates how much the university has done to achieve its mission through transferring knowledge and technology to the public. It quantifies the degree to which the university's mission is achieved through all knowledge and technology transfer activities. A UKTTEI of 100 represents the highest effectiveness level a university can possibly achieve. Any index below 100 reveals some opportunity for improvement in the university's knowledge and technology transfer. A UKTTEI below 30 may imply the ineffectiveness of the activity at the university.

This model also enables the identification of the areas where the university is performing well or underperforming by looking at the performance values of the UKTT mechanisms and their groups. If a UKTT mechanism is associated with a low performance value more managerial attention and resources may be needed to improve the performance of the mechanism.

A longitudinal study can be conducted to keep track of the UKTT effectiveness of the university over the years. Data will be collected and the model is applied for each year. Any improvement or decline in any performance areas can be identified and recommendations for actions can be made.

3.4.3.2 Application 2: Evaluation of UKTT Effectiveness of a Group of Universities.

Another application of the model is to evaluate and compare the effectiveness of a group of universities. The general process to evaluate UKTT effectiveness among a group of universities is similar to the process described above. The procedure to develop and implement the model is the same, but there are important differences. Specifically, the following points should be addressed:

- The universities to be compared should be selected to form a homogenous group for comparison. They should be comparable to each other in several aspects such as number of researchers, total research expenditures, and other major criteria. More importantly, these universities should reflect similar focus on the UKTT Objectives. In other words, the universities in the group should have similar strategic orientation with regard to knowledge and technology transfer. It is not rational to compare the knowledge and technology transfer activity between a teaching university and a research intensive university, or an income-generation oriented research university versus a knowledge-generation oriented counterpart. Specifically the group of universities will share the same set of mission and objectives as well as the prioritization of the objectives in the model. A good source to categorize universities is the Carnegie Classification of Institutions of Higher Education ™. This foundation provides a rich database of US universities and classifies research universities as very high research activity, high research activity, and doctoral/research universities [*].

- The experts participating in the Expert Panels do not come from only one university but all universities in the group. Maximum values of the metrics should reflect the potential performance of all universities in the group. It is important that all universities are represented in the expert panels.

Thus, the group of universities under investigation will share the same HDM structure with the same elements and contribution values. The only differentiating factor among them is the actual measurements of the metrics which are obtained for individual

[*] http://classifications.carnegiefoundation.org

universities, and the UKTTEI of each university will be determined following the process described in Application 1.

$UKTTEI_u$: UKTT Effectiveness Index of University *u*

$u = 1,..U$ with U : number of universities in the comparison group.

If

$$UKTTEI_u > UKTTEI_{u+n}$$

It is concluded that university *u* has a higher TT effectiveness than university *u+n*

This procedure will rank the universities in the group in UKTT effectiveness. It also allows identifying areas where a university is outperforming or underperforming its peers. The best performing university in an area, e.g. a UKTT mechanism, can act as a benchmark for other universities to improve. Due to time constraints, this study will conduct Application 1 only.

CHAPTER 4: DEVELOPMENT OF RESEARCH MODEL

4.1 The Conceptual Hierarchical Decision Model (HDM).

The overall objective of the study is to examine how the different knowledge and technology transfer mechanisms contribute to the UKTT mission of the universities. Therefore the top level of the HDM is the mission of the universities in transferring knowledge and technology to the public and the bottom level includes the specific transfer mechanisms. The mission is a general statement about the overall goal of the universities and is too broad to allow meaningful judgmental connections between the mission and the mechanisms level. Thus the mission is usually broken down to more specific objectives that allows the judgers to easily make mental linkages among the elements. The next level down in the HDM consists of the UKTT objectives.

Due to the different nature of the knowledge and technology transfer mechanisms that are employed by the universities, the transfer mechanisms at the bottom level will be grouped in distinct categories in such a way that enables preferential comparisons among them. As a result an intermediate level is needed between the objective level and the specific transfer mechanism level.

In order to evaluate the performances of the UKTT mechanisms, indicators for each and every mechanism should be determined and measured. This level of indicators can be added to the HDM; however it is considered an addendum to the hierarchy.

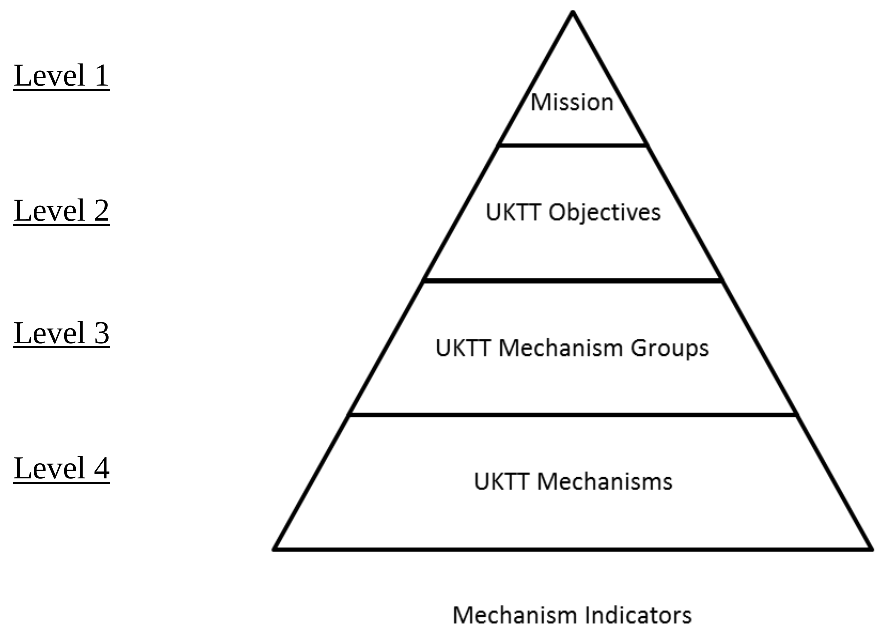


Figure 8: Conceptual hierarchical decision model for the research

In the following sections, the elements on each HDM level are determined.

4.2 Expert Panel Formation

4.2.1 Identification of Required Expertise

A strategic study that applies a hierarchical decision model approach is usually examining an over-arching problem that requires putting together a range of expertise. In this study three types of expertise are sought. The top level requires experts who are in administrative positions and have a strategic understanding of the overall objectives of the knowledge and technology activity taking place at their institutions. The bottom levels, i.e. UKTT technology transfer mechanisms and the indicators, require people with hands-on experience within each UKTT group. The challenge is at the intermediate level between the objectives and the mechanism groups. Here the judges should have knowledge bridging the strategic level and the operational level.

Three groups of experts invited to take part in the model development were identified as follows:

(1) Expert Group 1: University Research Administrators (UA)

This group consists of administrators who oversee the research and technology transfer at universities, or people at positions that provide them with a grasp of the overall knowledge and technology transfer at their institutions. In this study the vice presidents for research at universities around the US were invited to join this expert group.

(2) Expert Group 2: Academic Researchers (AR)

These are people who study the field of academic technology transfer so they often have knowledge of the field spanning from strategic issues to the mechanics of individual transfer mechanisms. These experts were identified from the literature and they come from countries around the world.

(3) Expert Group 3: Technology Transfer Managers (TM)

These experts include directors or licensing directors of technology transfer offices and directors of entrepreneurship centers or technology commercialization centers at universities.

The experts in groups 2 and 3 also helped to develop the desirability curves of the metrics.

4.2.2 Identification of Experts

The following methods were used to identify potential candidates for the expert groups:

(1) Social network analysis

A comprehensive search in the literature was done to identify researchers with high numbers of research publications who received high numbers of citations on the topic. Related papers as indicated by the database were also looked at. This task was to find prominent researchers for Expert Group 2.

To find candidates for the expert groups 1 and 3, a list of about 60 US universities that were selected based on their rankings of technology transfer performance was compiled, and then invitations to participate in the research were sent out to the vice president for research and the technology transfer managers at these universities.

(2) Snowball sampling

To find more potential candidates for the expert groups the identified experts were contacted and asked to recommend other experts in the field who they consider to be qualified for the study.

(3) Personal connections

The researcher of this study attended the 2013 Annual Meeting of the Association of Technology Transfer Managers (AUTM) and met with several technology transfer managers from universities around the country. Through this opportunity many new potential experts were contacted.

After identifying the lists of potential candidates, invitations were sent to them and responses were received over a period of a few months. The criteria for selecting the experts mentioned in section 3.3.5 were observed. However in the implementation of this study, these criteria were compromised with the willingness to participate of the invited persons.

4.2.3 Final Expert Groups.

The final list of experts who agreed to participate and responded to the research instruments is given in APPENDIX C. Expert Group 1 has 3 experts, Expert Group 2 has 22 experts, and Expert Group 3 has 10 experts.

4.3 Development of Research Instruments

In this study online research instruments were utilized to improve response time and save papers. Two types of research instruments are used for the research model.

Type 1: *Instruments to verify the linkages between the elements of the model, particularly the linkages between a lower level and an upper level*. There is one instrument for each level with respect to one element on the immediate upper level. These instruments ask the expert to verify, by choosing Yes or No, if there is a "linkage" from an element on a lower level to an element on the upper level. For instance, is there a linkage between UKTT Objective 1 "advance the knowledge base of society" to the UKTT mission? A "Yes" means the element on the lower level is significant and contributes to the element on the upper level. In this model, the elements on the Objective level and the UKTT mechanism group level were verified by the experts. Type 1 instruments were developed using Qualtrics software available at PSU.

Type 2: *Instruments to quantify the relative importance of the elements in the model through pair-wise comparison process*. All levels of the model were quantified. These instruments were developed in Qualtrics to obtain the experts' judgments, and the judgment results were entered into the ©HDM software available at the ETM department to come up with the relative weight for each of the elements in the model.

Samples of these online research instruments are provided in APPENDIX D.

4.4 HDM Level 1 - the Economic Mission of Universities.

The top level in the MOGSA model is the mission of the organization, i.e. the research university in this study. As this research adopts the organizational approach, the UKTT effectiveness in this study is defined as the degree to which the university's mission is achieved through its knowledge and technology transfer activities.

The definition of this element is drawn from the literature and published materials such as mission statements of research universities. This mission can be derived from the mission statements of most research universities. For instance, MIT states in its mission: "The Institute is committed to generating, *disseminating*, and preserving knowledge, and to working with others to bring this knowledge to bear on the world's great challenges"[*] . The mission of The Johns Hopkins University is to educate its students and cultivate their capacity for life-long learning, to foster independent and original research, and *to bring the benefits of discovery to the world* [†]. University of Washington's mission is to

[*] http://web.mit.edu/facts/mission.html

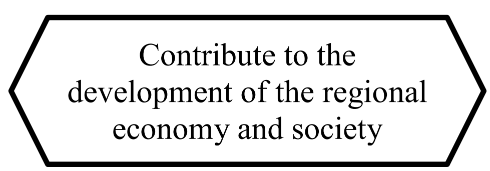
[†] http://webapps.jhu.edu/jhuniverse/information_about_hopkins/about_jhu/mission_statement/index.cfm

disseminate knowledge through the classroom and the laboratory, scholarly exchanges, creative practice, international education, and *public service* [*].

Within the scope of this study, we are not examining all missions of a university as a whole, but we particularly focus on the third mission, the economic development mission. This study will use the definition by Eztkowitz in his studies - in which the third mission of universities is “to contribute to the development of the regional economy and society”[†].

It is noteworthy that this research looks at the mission of the university, not that of the technology transfer office within the university. Most TTOs have mission statements, but as mentioned earlier the scope of work of TTOs does not represent the entire spectrum of knowledge and technology transfer from universities to the society.

HDM Level 1: university mission of knowledge and technology transfer



[*] http://www.washington.edu/home/mission.html
[†] The first two missions of universities are teaching and research

4.5 HDM Level 2 - Objectives of Universities with Respect to Knowledge and Technology Transfer.

The next level in the MOGSA hierarchy includes the objectives of the universities with regard to knowledge and technology transfer. UKTT objectives are the elaboration of the UKTT mission. Formal UKTT objectives are usually not explicitly stated by the universities, and they might be expressed in different ways by different universities. The researcher examined the published materials of the universities in the US and tried to determine the common objectives of the universities in implementing knowledge and technology transfer. As a result, five common UKTT objectives among the universities are presented below.

O_1: *Advance the knowledge base of the society.*

=> Transferring new scientific knowledge to the society so that the new knowledge can be widely accessible and used by the general public. The advancement of the knowledge base of the society may benefit individuals as well as business entities within that society.

O_2: *Facilitate innovations in the society.*

=> Bridging the gap between promising research and useful applications; promoting the wide-spread adoption of value added technologies and services in the society. Thus it contributes to the social-economic development of the regions and countries.

O_3: Help develop the economy of the region, state, and the nation.

=> Creating new products and services; as well as new jobs and businesses through the transfer of advanced technologies to outside parties who are seeking to commercialize the technologies, spin-offs from universities, or start-ups from the business incubators.

O_4: Foster an innovative and entrepreneurial culture among the researchers.

=> Enhancing the university's innovation and research capacity. Through UKTT, the university attracts, develops and retains application/translation-oriented faculty members, and provides incentives and rewards to the researchers so that they continue to work better. The researchers will be motivated to work more closely with industry. The objective also defines and enriches the educational experience of students at the university.

O5: Financial return from research spending.

=> Effectively managing the university's intellectual properties, ensuring the appropriate financial return on the university's research investment and other funding sources in research activities, and contributing to the funding of future research at the university. This is particularly important for public universities where funds are provided by the state or (outside the U.S.) national governments, since it is a responsibility of the university to protect and enhance the impact of this public investment. For private universities, financial return is also important from a business operations perspective, but less important from society's standpoint.

These five UKTT Objectives were verified by the experts. At least 85% of the experts agreed that each UKTT Objective contributes to the UKTT Mission. Therefore no objective was dropped and all these five UKTT objectives are retained in the model. Results are given in APPENDIX G-1.

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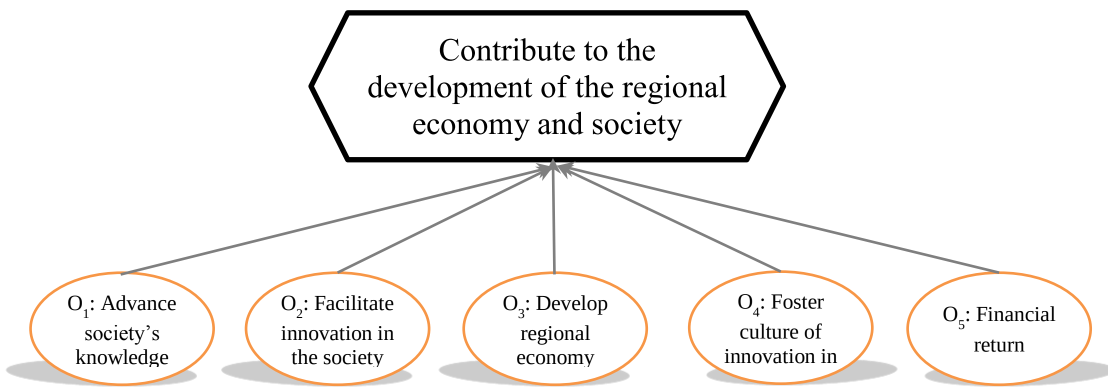

Figure 9: UKTT Objectives that contribute to the UKTT Mission

4.6 HDM Levels 3 and 4 - Technology Transfer Mechanism Groups and Specific Mechanisms within the Groups

As presented earlier this study investigated a wide range of university TT mechanisms, spanning from information provision to institutional vehicles. Information about the UKTT means or mechanisms were gathered from the literature and other published sources such as the *Technology Transfer Handbook* developed by the Federal Laboratory Consortium*. However due to the great diversity of these mechanisms, comparing may be illogical due to their different natures. For instance it does not make sense to compare a consulting contract and a technology incubator as the former is a legal document, while the latter is an institution, to say nothing of their contrasting scales. To remedy this paradox, mechanisms which share similar characteristics are grouped together. Therefore, the UKTT mechanism level in this model is broken into two parts: one representing the groups of UKTT mechanisms, and the other representing the specific mechanisms belonging to each group. This division helps the experts avoid comparing two vastly different mechanisms; and by comparing groups of mechanisms, they can make more sensible judgments.

A great number of knowledge and technology transfer mechanisms have been introduced in the literature; however this study identified 27 significant mechanisms which are then classified in 10 distinct groups. These groups of knowledge and technology transfer mechanisms range from means to disseminate information about knowledge and technologies to the public to institutional setups such as technology commercialization centers. Descriptions of the specific mechanisms in the 10 groups are given in APPENDIX E.

The experts were asked to verify the linkages (relationships) of the 10 UKTT mechanism groups to each of the UKTT objectives, and responses were collected (see APPENDIX D

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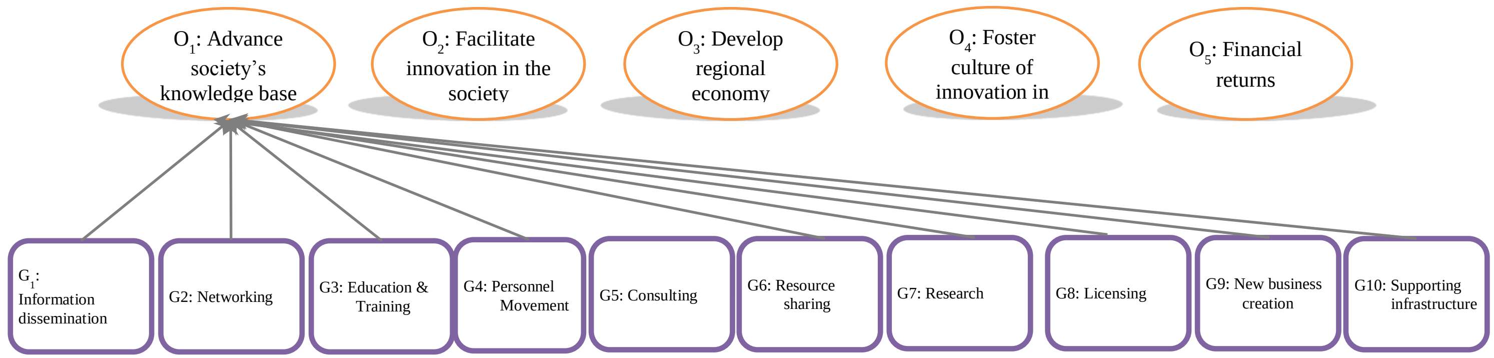
* http://www.federallabs.org/pdf/ORTA_Handbook.pdf

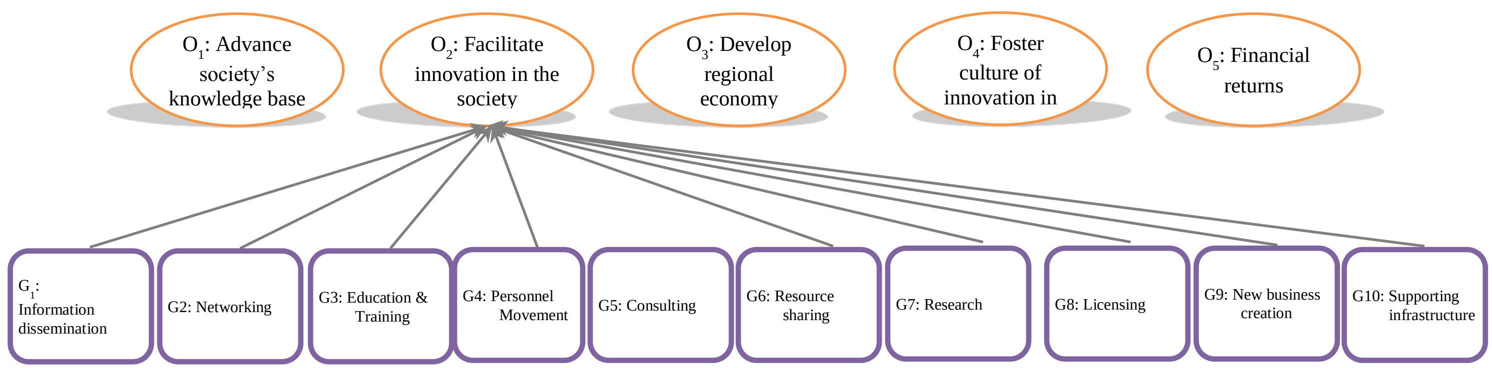
for the samples of the instruments used). Only linkages that were agreed on by at least 80% of the experts asked were retained in the model. Results show that UKTT group 5 “Consulting” does not significantly contribute to UKTT Objectives 1, 2, 4, and 5. UKTT group 6 “Resource Sharing” does not contribute to UKTT Objectives 4 and 5. UKTT objective 5 “Financial Return” is supported by only UKTT group 8 “Licensing” and group 9 “Startups” (see APPENDIX G-2 for individual experts’ verification). Table 13 summarizes the verification results.

	O1	O2	O3	O4	O5
G1	Yes	Yes	Yes	Yes	No
G2	Yes	Yes	Yes	Yes	No
G3	Yes	Yes	Yes	Yes	No
G4	Yes	Yes	Yes	Yes	No
G5	No	No	Yes	No	No
G6	Yes	Yes	Yes	No	No
G7	Yes	Yes	Yes	Yes	No
G8	Yes	Yes	Yes	Yes	Yes
G9	Yes	Yes	Yes	Yes	Yes
G10	Yes	Yes	Yes	Yes	No

Table 13: Results of verification by experts of the linkages between UKTT mechanism groups (G) and UKTT objectives (O)

These linkages are presented graphically in the following figure.


O1: Advance society's knowledge base
O2: Facilitate innovation in the society
O3: Develop regional economy
O4: Foster culture of innovation in
O5: Financial returns
G1: Information dissemination
G2: Networking
G3: Education & Training
G4: Personnel Movement
G5: Consulting
G6: Resource sharing
G7: Research
G8: Licensing
G9: New business creation
G10: Supporting infrastructure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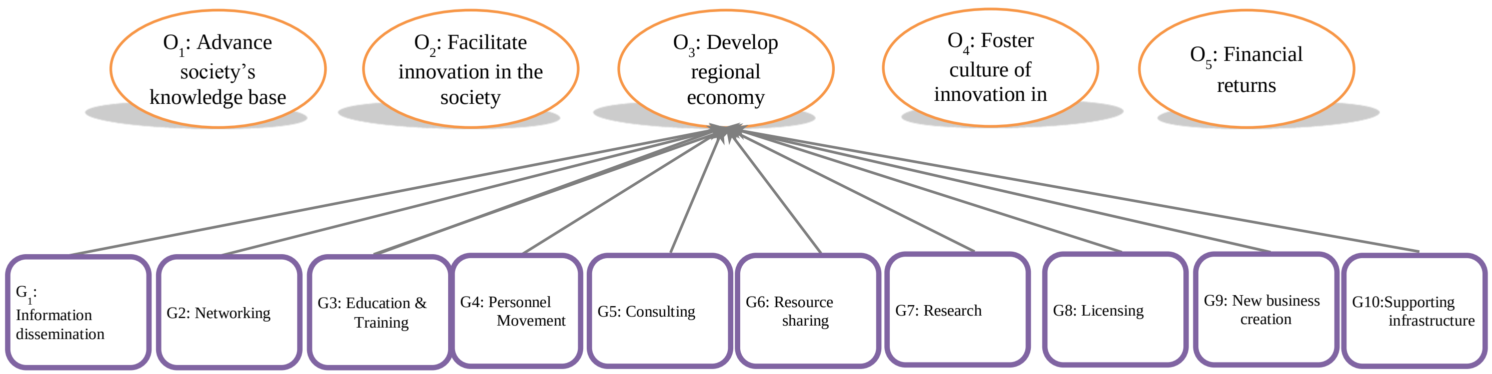
G4: Personnel Movement
G5: Consulting
G6: Resource sharing
G7: Research
G8: Licensing
G9: New business creation
G10: Supporting infrastructure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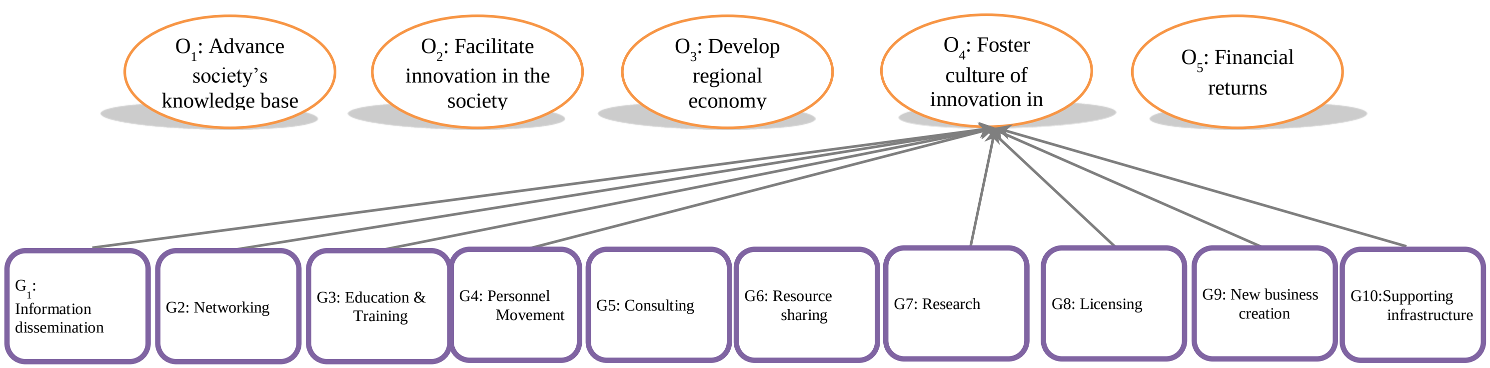
G9: New business creation
G10:Supporting infrastructure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G10:Supporting infrastructure

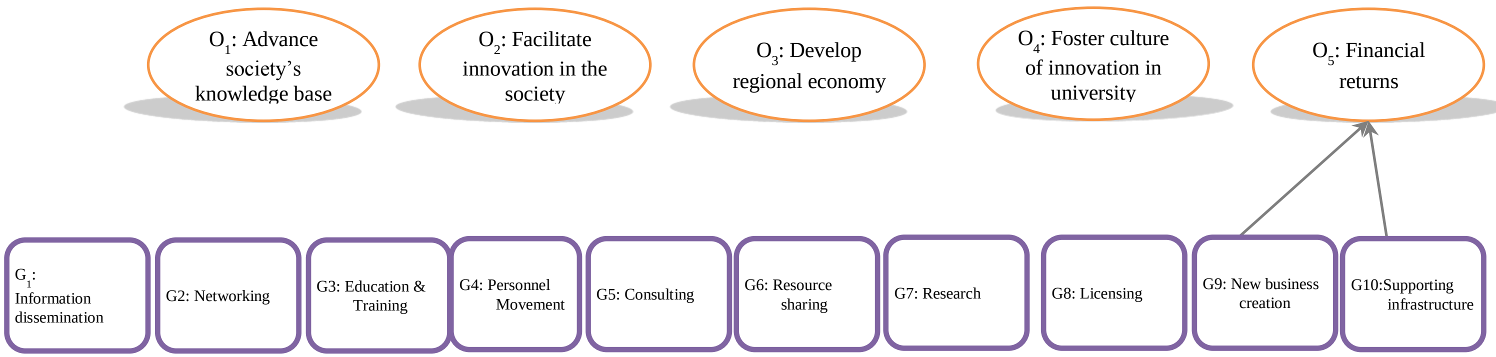
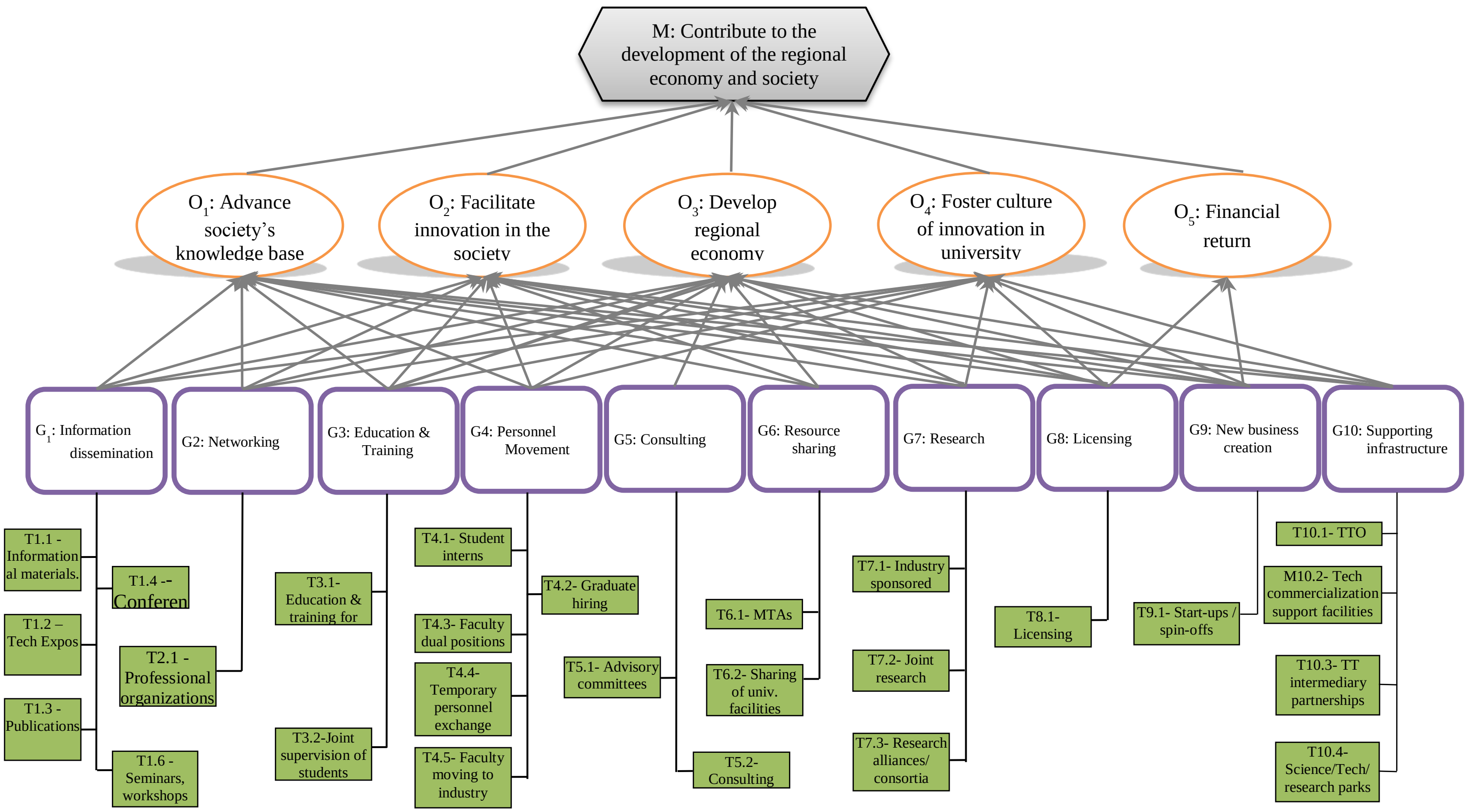


Figure 10: Linkages from the UKTT Mechanism Groups to each of the UKTT Objectives

4.7 Final Hierarchal Decision Model

The final HDM for the study with hierarchical levels, elements, and the linkages is presented in Figure 11.

Figure 11: UKTT Effectiveness Evaluation HDM



4.8 Technology Transfer Mechanism Indicators and Metrics

In addition to the four official levels in the HDM, the study identified the indicators and metrics of the UKTT mechanisms. Indicators are criteria by which a UKTT mechanism can be evaluated. For instance indicators of licensing mechanism may include the number of licenses and dollar size of a license, while a metric is a specific measurement of that indicator, for example the number of new licenses made in a given year. A good indicator is one that can well represent the performance of the mechanism. A metric is defined in a way that enables the obtainment of real data of the mechanism. In this study the indicators of the UKTT mechanisms were compiled from the literature review and public sources. The metrics were defined for data obtained in a given year and where possible normalized by the number of researchers at the university, for instance the number of journal papers per researcher. Some metrics are not normalized per researcher because the data are too small, for example the number of new startups in a given year. Ranges of values of the metrics were also determined. This list of indicators, metrics, and value ranges was pre-discussed in person with some technology transfer managers to ensure its appropriateness.

The description of the indicators and metrics of the UKTT mechanisms is provided in APPENDIX F.

CHAPTER 5: RESULTS OF MODEL QUANTIFICATION

5.1 Pairwise Comparisons of the UKTT Objectives

In this step the relative contribution values or weights of the UKTT Objectives were quantified by Expert Group 1 (university administrators) through a pairwise comparison process. Research Instrument 2.2 (APPENDIX D-2) was developed and sent to the experts to ask for their pairwise comparison judgments. Three university administrators responded to this instrument, and their judgments are as follows (APPENDIX H-1):

Expert	O1: Advance society's knowledge base	O2: Facilitate innovation in society	O3: Develop regional economy	O4: Foster culture of innovation in university	O5: Financial return
UA1	0.07	0.07	0.03	0.09	0.74
UA2	0.2	0.21	0.15	0.15	0.29
UA3	0.12	0.19	0.25	0.37	0.07

The judgments show three different orientations of the three universities. The first university, represented by UA1, places heavy emphasis on the financial return objective of the knowledge and technology transfer activity. The third university puts more weight on the development of internal innovation culture at the institution. The second university takes a more intermediate position. In this study we will respect the different orientations of the universities as far as their objectives in knowledge and technology transfer are concerned, and treat them separately. These three universities will be used to demonstrate the application of the model for universities with different orientations in the scenario analysis section.

5.2 Pairwise Comparisons of the UKTT Mechanism Groups

Research Instrument 3.2 (APPENDIX D-2) was sent out to the Experts in Group 2 and some in Group 3 to ask them to quantify the relative contribution values of the UKTT Mechanism Groups to each of the five UKTT Objectives. Judgment results are given in APPENDIX H-2. The relative importance values of the UKTT mechanism groups (G) with respect to the UKTT Objectives (O) are summarized in Table 14.

	O1	**O2**	**O3**	**O4**	**O5**
G1	0.14	0.12	0.11	0.11	-
G2	0.08	0.1	0.11	0.1	-
G3	0.12	0.11	0.11	0.11	-
G4	0.16	0.20	0.1	0.12	-
G5	-	-	0.16	-	-
G6	0.15	0.14	0.13	-	-
G7	0.16	0.09	0.11	0.29	-
G8	0.07	0.08	0.07	0.14	0.65
G9	0.07	0.08	0.05	0.06	0.35
G10	0.05	0.08	0.05	0.07	-
Total	***1.00***	***1.00***	***1.00***	***1.00***	***1.00***

Table 14: Relative weights of the mechanism groups to the objectives

All experts were considered consistent in their judgments (consistency indices less than 0.10)

5.3 Pairwise Comparisons of the UKTT Mechanisms and Indicators

The next step was to ask the experts to quantify the relative importance values of the specific mechanism within a group of the mechanisms, and the importance values of the indicators associated with each mechanism. If the mechanism is identified with only one indicator, there is no need for a pairwise comparison. Research Instruments 4.2 and 4.3 (APPENDIX D- 5 and 6) were developed for this purpose. The judgment results for this step are provided in APPENDIX H-3 and APPENDIX H-4. The relative importance values (*w*) of the UKTT mechanisms within the groups and their indicators are summarized in Table 15.

Group	Mechanism	*w(T)*	Indicator	*w(I)*
G1: Information Dissemination	T1.1: Informational materials	**0.19**	Online materials	**0.52**
			Printed materials	**0.48**
	T1.2: Technology expositions	**0.20**	No. of tech expos participated	**1.00**
	T1.3: Journal publications	**0.18**	No. of journal papers	**0.57**
			No. journal paper citations	**0.43**
	T1.4: Conferences	**0.23**	No. of conference papers	**0.60**
			No. of conference paper citations	**0.40**
	T1.5: Seminars/workshops	**0.20**	No. of seminars/workshops	**0.54**
			No. of attendees at the seminars	**0.46**
G2: Professional Networking	T2.1: Professional networking	**1.0**	No. of researchers with professional memberships	**0.57**
			No. of memberships per researcher	**0.43**
G3: Education & Training	T3.1: Education&training programs for industry	**0.59**	No. of students working in industry	**0.48**
			No. of faculty conducting short training courses	**0.52**
	T3.2: Joint supervision of students	**0.41**	No. of students jointly supervised	**1.00**
G4: Personnel Movement	T4.1: Student internships	**0.18**	No. of students with internships in industry	**1.00**

	T4.2: Graduate hiring	**0.23**	No. of university graduates hired by tech based industries	**1.00**
	T4.3: Dual positioned faculty	**0.22**	No. of faculty with dual positions in university and industry	**1.00**
	T.4.4: Temporary Personnel Exchange	**0.18**	No. of faculty temporarily exchanged with industry	**1.00**
	T4.5: Faculty moving to industry	**0.19**	No. of faculty permanently moving to industry	**1.00**
G5: Consulting	T.5.1: Advisory committees	**0.49**	No. of faculty serving industry advisory boards	**1.00**
	T.5.2: Consulting	**0.51**	No. of faculty conducting consulting for industry	**0.63**
			No. of consulting agreements	**0.37**
G6: Resource Sharing	T.6.1: Material Transfer Agreements (MTAs)	**0.47**	No. of MTAs	**1.00**
	T.6.2: Sharing of university facilities	**0.53**	No. of companies using university facilities	**1.00**
G7: Research	T.7.1: Industry sponsored research	**0.34**	No. of industry sponsored research projects	**0.54**
			Average size of a sponsored research, $	**0.46**
	T.7.2: Joint research	**0.31**	No. of joint research projects	**1.00**
	T.7.3: Research alliance	**0.35**	No. of research alliances/consortia with industry	**0.30**
			No. of faculty participating in research alliances	**0.36**
			No. of companies participating in research alliances	**0.34**
G8: Licensing	T.8.1: Licensing	**1.0**	No. of new executed licenses	**0.27**
			Average license income	**0.29**
			No. of technologies transferred	**0.44**
G9: New Business Creation	T.9.1: Startups	**1.0**	No. of new startups	**0.64**
			No. of faculty involved in startup business	**0.36**
G10: Supporting Infrastructure	T.10.1: TTO	**0.29**	No. of licensing FTEs	**1.00**
	T.10.2: Tech commercialization support facilities	**0.27**	No. of tech commercialization support facilities	**0.41**
			Average number of projects supported at one facility	**0.59**

	T.10.3: Tech transfer intermediary partnerships	**0.22**	No. of partnerships with TT intermediaries	**1.00**
	T.10.4: Research/Tech/Science park	**0.22**	No. of parks the university participates in	**0.27**
			No. of faculty involved in research at the parks	**0.40**
			No. of companies participating in a park	**0.33**

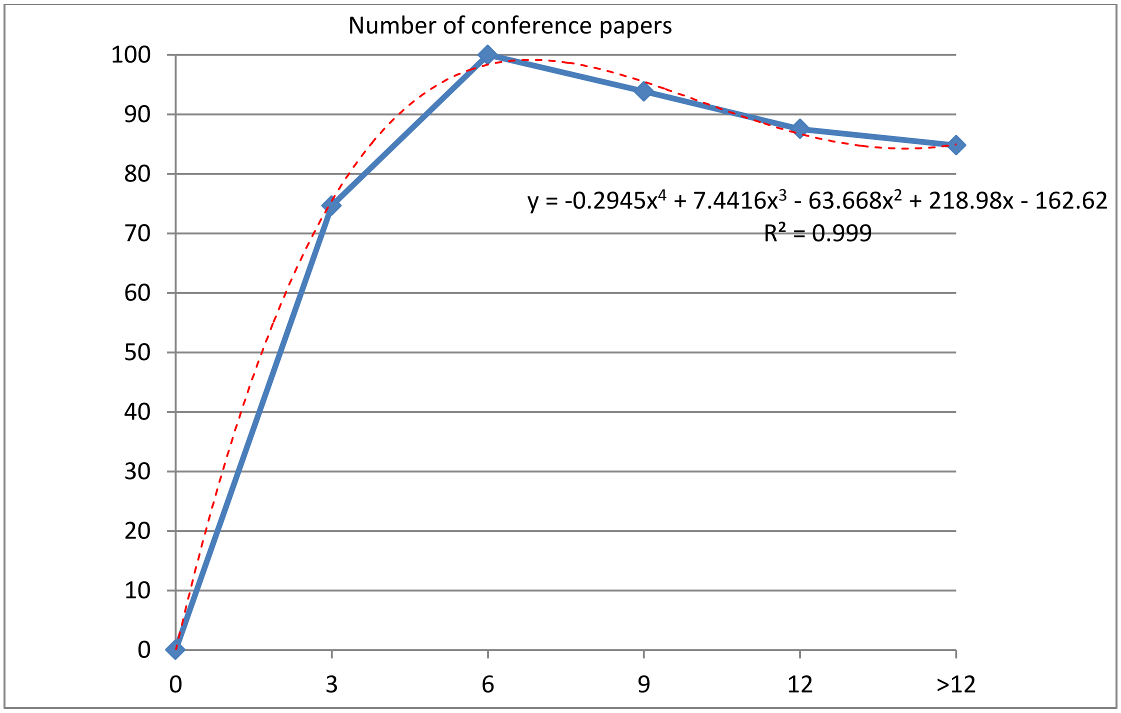
Table 15: Relative importance values of the UKTT mechanisms and their indicators

All experts were considered consistent in their judgments (consistency indices less than 0.10)

5.4 Desirability Curves of the Metrics

The purpose of this research step is to develop the desirability curves for the metrics of the UKTT mechanisms. Research Instrument 4.4 (APPENDIX D-7) was sent to the experts to ask for their judgments of the desirable values for the metrics. For each value specified in the value range of a metric the experts will provide a corresponding desirable value. For instance the expert will judge how desirable it is having 1, 3 or 5 new startups in a given year on a 0-100 point scale. Using these desirability values the desirability curves of all the metrics were developed. They are presented in APPENDIX I.

For example, the desirability curve for the metric “number of conference papers” is:



The desirability curve was developed using MS Excel. Excel provides a number of utilities for the graph. For instance it can determine the mathematical function of the graph based on the provided data points, and the correlation R to indicate the goodness of fit of the mathematical function to the actual graph. The desirability value of any metric value can be derived using either the actual graph (solid line) or the fitted mathematical function (dashed line). For simplicity this study uses the actual desirability curves to obtain the desirability values for the case studies.

5.5 Final Hierarchical Decision Model with Contribution Values.

With the availability of the original set of pairwise comparison results of all the elements in the model, the contribution values on each level with respect to the top level – UKTT Mission- can be computed using (Equation 1) and (Equation 2). The results are presented in Figure 12.

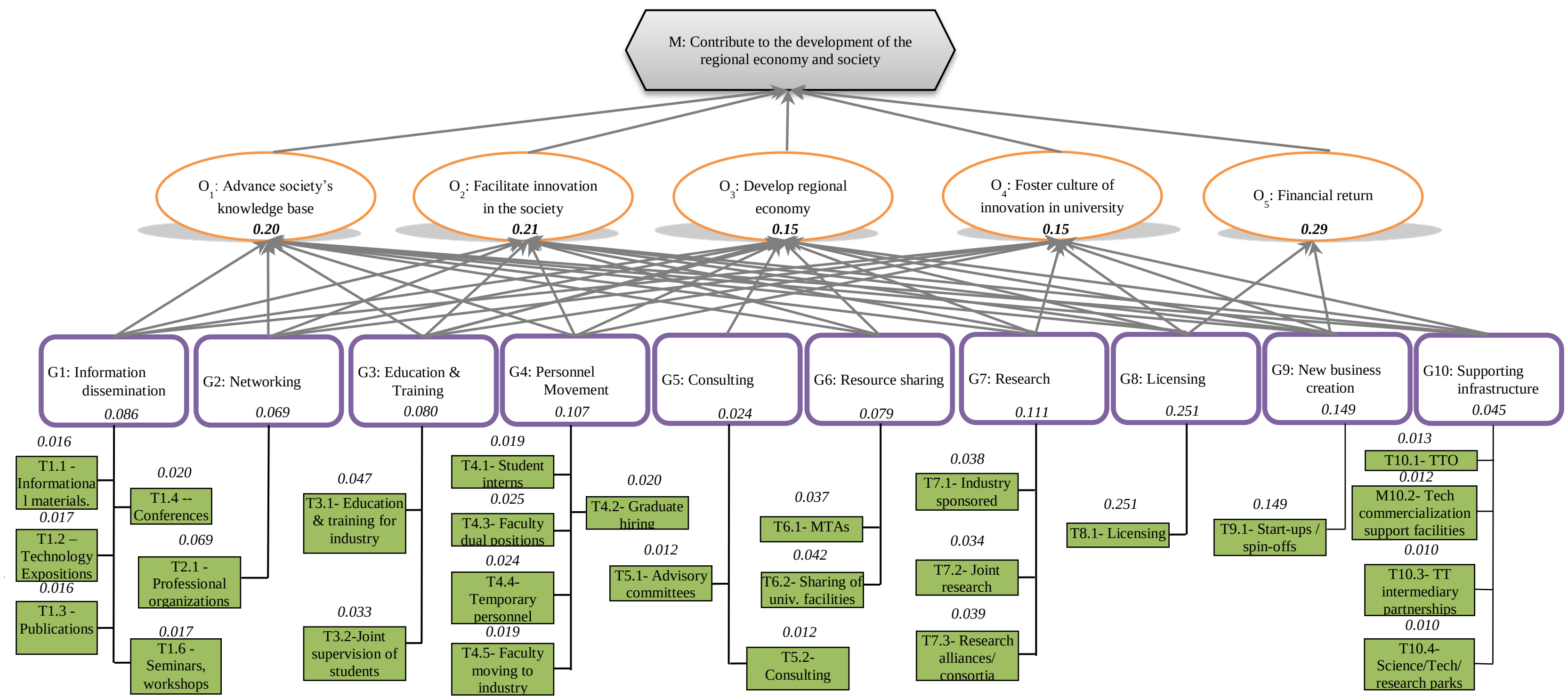


Figure 12: Contribution values of the elements in the model with respect to the UKTT Mission

5.6 Portland State University as the Baseline Model

To conduct analyses of the results it is necessary to identify a baseline model for the analysis. A baseline model is the initial model with the original data set obtained from the model quantification process. Changes will be made according to the different scenarios and compared against this baseline scenario. This study uses Portland State University as the baseline case. The Baseline Model has the UKTT Objective weights provided by expert UA2, initial data of the contribution values of the elements in the model, and desirability curves developed. The information is summarized in Table 16, which presents the relative contribution values or weights of the UKTT Objectives, Mechanisms Group, Mechanisms within the groups with respect to the overall UKTT Mission, and relative weights of the Indicators to their respective Mechanisms from Columns 1 to 9.

The actual measurements of values of the metrics for Portland State University are provided in Column 10. A number of figures in this column are real data collected from various sources at PSU. However some figures are not readily available, and thus have to be estimated. For instance the number of citations of the researchers' journal publications can be obtained from citation management databases such as SciVerse Scopus of Elsevier or the Science Citation Index of Thomson Reuters. Unfortunately PSU does not have subscriptions to these databases. As this study covers a wide range of knowledge and technology transfer mechanisms, data for many of these mechanisms are not yet track of by the university, for instance, the number of graduates hired by technology based industry, number of faculty members permanently moving to work in industry, etc.

The desirability values of the mechanism metrics in column 11 are derived from the developed desirability curves (See APPENDIX J-1). Then the performance values of the mechanisms are calculated using (Equation 3). These performance values represent a gap to the highest score of 100, which is the Performance Gap in column 13. These Performance Gaps of the mechanisms reveal an opportunity for the improvement of the mechanisms. The Improvement Potential value for a mechanism is the product of its relative contribution weight to the mission, w(T), and the Performance Gap. Thus the higher the contribution weight and the performance gap of a mechanism are, the greater the opportunity or room for improvement of the mechanism is in order to increase the overall Effectiveness Index. Column 17 presents the percentage of current contributions of the mechanisms to the Effectiveness Index.

Mission (M)	*Obj.*	*w(O)*	*Group (G)*	*w(G)*	*Mec. (T)*	*w(T)*	*r(wT)*	*Ind. (I)*	*w(I)*	*Metric. value (E)*	*desire. value (V)*	*Mec. Perf (P)*	*Perf. Gap (PG)*	*Imp. Pot (IP)*	*r (IP)*	*C(T), w(T)xP*	*%EI*	*r(%EI)*	**Effectiveness Index (EI)**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**	**(15)**	**(16)**	**(17)**	**(18)**	**(19)**
	O1	*0.20*	G1	*0.086*	T1.1	**0.016**	19	I.1.1.1	0.52	2	60	**69**	**31**	0.51	22	1.12	2.4%	12	**47.4**
	O2	*0.21*						I.1.1.2	0.48	2	78								
	O3	*0.15*			T1.2	**0.017**	17	I.1.2.1	1.00	0	0	**0**	**100**	1.72	8	0.00	0.0%	24	
	O4	*0.15*			T1.3	**0.016**	20	I.1.3.1	0.57	1	20	**46**	**54**	0.84	14	0.71	1.5%	16	
	O5	*0.29*						I.1.3.2	0.43	30	80								
					T1.4	**0.020**	14	I.1.4.1	0.60	2	50	**64**	**36**	0.71	17	1.27	2.7%	10	
								I.1.4.2	0.40	30	85								
					T1.5	**0.017**	17	I.1.5.1	0.54	1	55	**57**	**43**	0.74	15	0.99	2.1%	14	
								I.1.5.2	0.46	50	60								
			G2	*0.069*	T2.1	**0.069**	3	I.2.1.1	0.57	80	90	**77**	**23**	1.57	10	5.28	11.2%	2	
								I.2.1.2	0.43	1	60								
			G3	*0.080*	T3.1	**0.047**	4	I.3.1.1	0.48	20	90	**85**	**15**	0.72	16	4.01	8.5%	3	
								I.3.1.2	0.52	20	80								
					T3.2	**0.033**	10	I.3.2.1	1.00	5	50	**50**	**50**	1.64	9	1.64	3.5%	8	
			G4	*0.107*	T4.1	**0.019**	15	I.4.1.1	1.00	20	65	**65**	**35**	0.67	18	1.25	2.6%	11	
					T4.2	**0.025**	11	I.4.2.1	1.00	70	90	**90**	**10**	0.25	26	2.21	4.7%	6	
					T4.3	**0.024**	12	I.4.3.1	1.00	10	40	**40**	**60**	1.41	12	0.94	2.0%	15	
					T4.4	**0.019**	15	I.4.4.1	1.00	1	20	**20**	**80**	1.54	11	0.39	0.8%	23	
					T4.5	**0.020**	13	I.4.5.1	1.00	1	80	**80**	**20**	0.41	24	1.63	3.4%	9	
			G5	*0.024*	T5.1	**0.012**	24	I.5.1.1	1.00	10	60	**60**	**40**	0.47	23	0.71	1.5%	17	
					T5.2	**0.012**	22	I.5.2.1	0.63	10	55	**56**	**44**	0.54	21	0.69	1.5%	19	
								I.5.2.2	0.37	1	58								
			G6	*0.079*	T6.1	**0.037**	8	I.6.1.1	1.00	5	15	**15**	**85**	3.15	4	0.56	1.2%	22	
					T6.2	**0.042**	5	I.6.2.1	1.00	20	55	**55**	**45**	1.88	7	2.30	4.9%	5	
			G7	*0.111*	T7.1	**0.038**	7	I.7.1.1	0.54	20	20	**48**	**52**	1.98	6	1.79	3.8%	7	
								I.7.1.2	0.46	230K	80								
					T7.2	**0.034**	9	I.7.2.1	1.00	1	30	**30**	**70**	2.41	5	1.03	2.2%	13	
					T7.3	**0.039**	6	I.7.3.1	0.30	0	0	**0**	**100**	3.88	3	0.00	0.0%	24	

					I.7.3.2	0.36	0	0							
					I.7.3.3	0.34	0	0							
G8	*0.251*	T8.1	**0.251**	1	I.8.1.1	0.27	22	45	**52**	**48**	12.00	1	13.08	27.6%	1
					I.8.1.2	0.29	450	100							
					I.8.1.3	0.44	8	25							
G9	*0.149*	T9.1	**0.149**	2	I.9.1.1	0.64	2	20	**25**	**75**	11.10	2	3.78	8.0%	4
					I.9.1.2	0.36	3	35							
G10	*0.045*	T10.1	**0.013**	21	I.10.1.1	1.00	3.5	50	**50**	**50**	0.65	19	0.65	1.4%	20
		T10.2	**0.012**	23	I.10.2.1	0.41	3	72	**53**	**47**	0.57	20	0.64	1.4%	21
					I.10.2.2	0.59	5	40							
		T10.3	**0.010**	25	I.10.3.1	1.00	3	70	**70**	**30**	0.30	25	0.69	1.5%	18
		T.10.4	**0.010**	25	I.10.4.1	0.27	0	0	**0**	**100**	0.99	13	0.00	0.0%	24
					I.10.4.2	0.40	0	0							
					I.10.4.3	0.33	0	0							

Table 16: PSU as the Baseline Model and the computation of its UKTT Effectiveness Index

Column:
(1) O: UKTT Objective
(2) *w(O):* relative contribution of the Objective to the Mission.
(3) G: UKTT Mechanism Group
(4) *w(P):* relative contribution of the Mechanism Group to the Mission.
(5) T: UKTT Mechanism
(6) *w(T):* relative contribution of the Mechanism to the Mission.
(7) r(wT): rank of the relative contribution of the Mechanism to the Mission
(8) I: Indicator of the Mechanism
(9) *w(I):* relative importance value of the Indicator to its Mechanism.
(10) E: value of the indicator’s metric (real or estimated data of the university)
(11) V: desirability value of the indicator’s metric (derived from the desirability curve of the metric)

(12) $P = \sum w(I) x V$. Performance value of the UKTT Mechanism
(13) $PG = (100-P)$. Performance Gap, representing the current performance value of the mechanism to the maximum potential
(14) $IP = w(T) x PG$. Improvement Potential of the mechanism
(15) $r(IP)$: rank of Improvement Potential of the mechanism
(16) $C(T) = w(T) x P$. Contribution of the Mechanism to the overall Effectiveness Index
(17) %EI: Contribution percentage of the Mechanism to the overall Effectiveness Index = (16)/EI
(18) r(%EI): rank of the contribution percentage of the Mechanism to the overall Effectiveness Index
(19) EI: Effectiveness Index of the university knowledge and technology transfer $= \sum w(T) x P$

The PSU Baseline Model shows that the overall UKTTEI of Portland State University is 47.4. This is an average score and the university has 52.6 points for improvement, theoretically. The five most important UKTT mechanisms in terms of contribution weights to the overall mission are (Column 6):

- ✓ T8.1 – Licensing (0.251)
- ✓ T9.1 – Start-up (0.149)
- ✓ T2.1 – Professional Networking (0.069)
- ✓ T3.1 – Education & Training for industry (0.047)
- ✓ T7.1 – Sharing of university facilities with industry (0.042).

They are also the five highest contributors to the Effectiveness Index of the university, (Column 17). Yet the five mechanisms with highest potential for improvement are different, including Licensing (T8.1), Startup (T9.1), Materials Transfer Agreements (T6.1), Research Alliances (T7.3), and Joint Research (T7.2), (Column14).

CHAPTER 6: ANALYSIS AND DISCUSSION OF THE MODEL QUANTIFICATION RESULTS

This section analyzes and discusses the results of the model judgment quantification. We examine how the final result would change according to different scenarios, e.g. if we assume the makeup of an expert group changes, or an individual judgment prevails over the group's judgment, or if the model is applied to different types of universities, etc. These analyses help to reveal the behavior of the model as well as identify the areas for improvement.

As stated in the scope of research, this study demonstrates the application of the model to evaluate the effectiveness of knowledge and technology transfer for a single university. An expansion of the scope to make comparisons among a group of comparable universities can be conducted in future research.

6.1 Disagreement Analysis

One common issue encountered in the judgment quantification of an HDM is the disagreement among the experts' judgments. The question of disagreement can be addressed by carefully examining the causes of the disagreement and analyzing the impact of the different alternatives on the final result of the model.

In this study, the disagreement of the experts is shown by the F-values provided by the ©HDM software. The F-value of a pairwise comparison result is then compared against the F-critical values at a significant level to make conclusions about the disagreement. In this study we use the significant level of 0.1 for the F-tests. On the second level of the model, UKTT Objectives, the disagreement among the three research administrators is not considered as each university represents a distinct strategic orientation in knowledge and technology transfer. They cannot be compared against each other. Our analysis is focused on the lower levels in the model which can be shared among the universities. The F-values of the second UKTT Mechanism Groups of the model are presented in APPENDIX H-2 and summarized in the following table.

Pairwise comparison	F-value	F-critical value
Level 3: UKTT Mechanism Groups		
UKTT Mechanism Groups with respect to UKTT Objective 1 "Advance knowledge base of Society"	1.85	1.80
UKTT Mechanism Groups with respect to UKTT Objective 2 "Facilitate innovation in Society"	6.48	3.78
UKTT Mechanism Groups with respect to UKTT Objective 3 "Develop regional economy"	5.83	3.46
UKTT Mechanism Groups with respect to UKTT Objective 4 " Foster culture of innovation in university"	4.58	1.84
UKTT Mechanism Groups with respect to UKTT Objective 5 "Financial return"	2.14	3.78

Table 17: F-values of the UKTT Mechanism Group with respect to the Objectives

The results show that the pairwise comparisons for the UKTT Mechanism Groups with respect to UKTT Objective 1 to UKTT Objective 4 do not have significant disagreement among the experts (F-value greater than F-critical value). Only the judgment quantification for the Mechanism Groups with respect to Objective 5 appears to have disagreement among the experts. This triggers the research need to understand what might have caused the disagreement and how this problem can be addressed.

6.1.1 Disagreement among the Experts Regarding the UKTT Mechanism Groups with Respect to the UKTT Objective 5 "Financial Return"

There are two UKTT Groups that contribute to UKTT Objective 5 "Financial return". They are Group 8 "Licensing" and Group 9 "New Business Creation". Details of the pairwise comparisons for these groups are presented in the following table.

Expert code	SPSS case	G8: Licensing	G9: New business creation
TM6	1	0.95	0.05
AR17	2	0.61	0.39
TM5	3	0.55	0.45
AR21	4	0.5	0.5
AR9	5	0.8	0.2
AR14	6	0.91	0.09
TM1	7	0.2	0.8
Mean		***0.65***	***0.35***
Minimum		*0.2*	*0.05*
Maximum		*0.95*	*0.8*
Std. Deviation		*0.24*	*0.24*

Table 18: Original results of expert judgments for contribution values of the two mechanism groups to UKTT Objective 5

The question now is what or who might have caused the high disagreement among these experts? To find out the answer, the data in Table 18 were entered into SPSS software to run a Hierarchical Cluster Analysis (HCA) which clusters the experts in groups according to the closeness of their judgments. The resulting Dendrogram reveals that there are 3 sub-groups of experts. Sub-group 1 includes TM6, AR14, and AR9 who emphasized on the “Licensing” mechanism. Sub-group 2 includes AR17, TM5, and AR21 who are more balanced on both mechanisms but are slightly skewed toward Licensing. Sub-group 3 consists of only TM1 who stressed the “New Business Creation” mechanism.

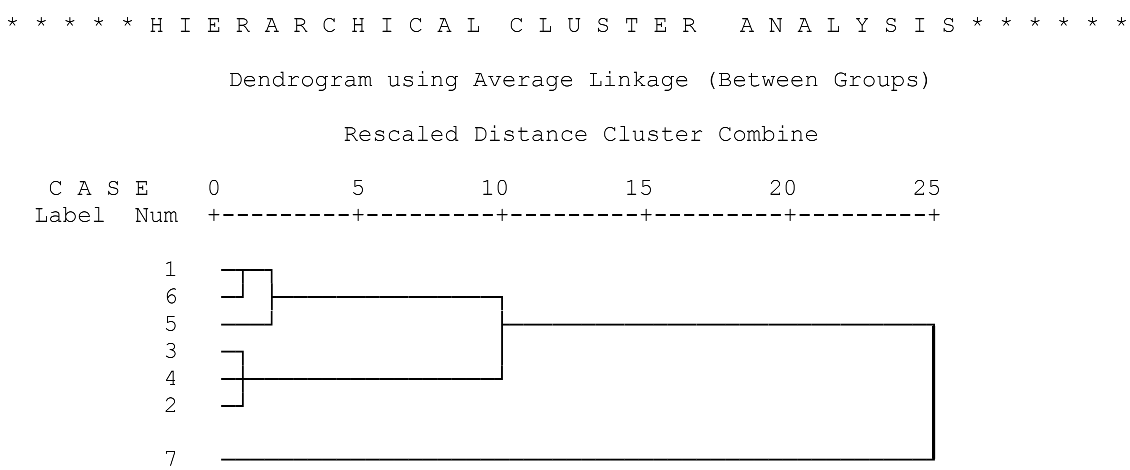


Figure 13: Cluster analysis of expert judgments in Table 18

It is clear to see that TM1 is the outlier of the group. We are now facing the decision about whether or not TM1's judgment should be excluded from the group. To answer this question we examine the impact of removing TM1 from the expert group on the final result of the model.

	Group w/ TM1	Group w/o TM1
Weight of "Licensing"	**0.65**	**0.72**
Weight of "New Business Creation"	**0.35**	**0.28**
F-value	*2.14*	*7.85*
F-critical value	*3.78*	*4.06*
UKTTEI	**47.4**	**47.9**

Table 19: Pairwise comparison of the UKTT Mechanism Groups with respect to Objective 5 without TM1 in the expert group.

The result shows that excluding TM1 as an outlier from the expert group for this judgment quantification significantly improves the agreement in the judgments among the remaining experts, however its impact on the final result of the model, the UKTT Effectiveness Index, is minimal with an increase of only 0.5 points. In addition there is a possibility that TM1's judgment is correct as opposed to the rest of the group because the true relative contribution values are unknown. Therefore the analyses following this section are done with the original results, meaning including TM1's judgment in this group.

6.1.2 Disagreement among the Experts Regarding Level 4 "UKTT Mechanisms and Indicators"

The same analytic procedure can be applied to examine the impact of the disagreements at the bottom level, including UKTT mechanism and their indicators on the final result. The F-values of the pairwise comparison results for the UKTT Mechanisms and Indicators are presented in APPENDIX H-3 and 4. While the judgment quantification results for the upper levels do not show significant disagreement among the experts, it is expected that the bottom level would present some disagreement. One reason could be the operational nature of the elements on the bottom level, UKTT Mechanisms and Indicators, as opposed to the strategic nature of the UKTT Objectives and Mechanism Groups. In addition, the expert group consists of both academic researchers and technology transfer managers for this level, which may reflect different perspectives in the judgments. In fact the pairwise comparison results show high disagreement for most of the mechanisms and their indicators.

Due to the large number of mechanisms and their indicators present in the model, this section demonstrates the analysis using one mechanism group. Group 7 "Research" is selected due to its high contribution value to the overall mission after Licensing and New Business Creation groups. There are three mechanisms within the Research Mechanism Group, including Industry sponsored research, Joint research, and Research alliance. The pairwise comparison result of these mechanisms exhibits significant disagreement among the experts (APPENDIX H-3-5). Using the Hierarchical Cluster Analysis, expert AR4 was identified as the distinct outlier in the group's judgments.

The results of this analysis are summarized in the following table.

	Original group including AR4	Group excluding AR4
Contribution of "Industry sponsored research" mechanism to the Mission	0.34	0.35
Contribution of "Joint research" mechanism to the Mission	0.31	0.26
Contribution of "Research alliance" mechanism to the Mission	0.36	0.38
UKTTEI	**47.4**	**47.3**

Table 20: Pairwise comparison of the Research Mechanisms to the Mission with and without AR4 in the expert group.

The above result shows that the disagreement among the experts in this judgment has a very small impact on the final result of the model. Again, it is worth noting to note that the purpose of this analysis is to not eliminate the disagreement in the judgments, but rather to explore the impact of it on the final evaluation result of the model.

6.2 Analysis of University's Strategic Knowledge and Technology Transfer Orientation

As stated earlier this model cannot be applied to compare universities with different strategic orientations with respect to knowledge and technology transfer, for instance a knowledge generating university versus a technology commercializing counterpart. Due to different strategic orientations, universities will have different priorities of the UKTT activities. The UKTT strategic orientation of a university is represented by the relative contribution values of the UKTT Objectives to the Mission on the second level in the HDM. This study received the judgments from the research administrators at three universities for the UKTT Objectives, and each response exhibits a different orientation for the institution. In this section, an analysis is conducted to see what implications can be drawn from the model when applied to universities with different strategic UKTT orientations. Note that we do not compare the universities directly with each other, but treat them as separate.

6.2.1 Strategic UKTT Orientations of the Three Universities Participating in the Research

In this part, we examine the three universities represented by the university administrators who provided the relative contributions of the UKTT objectives to the mission in this study. The question is how the results of the HDM change under each orientation of the universities. Information about these three universities is presented in the following table.

	UA1	**UA2 (PSU)**	**UA3**
Type	Public	Public	Public
Student population	29200	29700	26200
Academic staff	1907	2592	1280
Research expenditure (2011)	69.6M	64.8M	29.8M
Carnegie Foundation classification	RU/H: Research Universities (high research activity)	RU/H: Research Universities (high research activity)	DRU: Doctoral/Research Universities

Table 21: Three universities participating in the study with relative contribution values of the UKTT objectives [(*)]

Using the same data for the UKTT metrics of PSU for all these three cases, the strategic UKTT orientation and final Effectiveness Index of each university are presented in the following table.

[*] Data sources include public sources, AUTM report, Carnegie Foundation's Classification of Institutions of Higher Education.

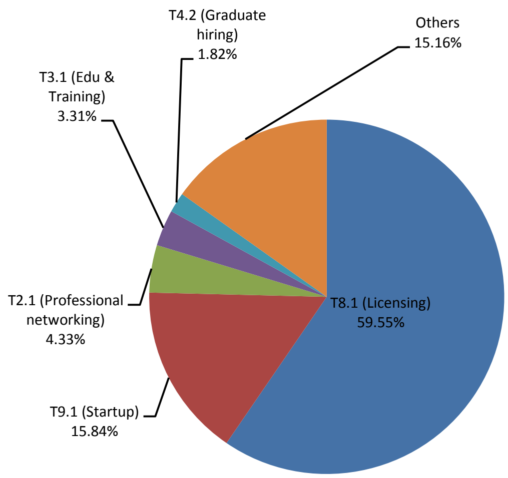
Univ.	O1: Advance society's knowledge base	O2: Facilitate innovation in society	O3: Develop regional economy	O4: Foster culture of innovation in university	O5: Financial return	**UKTTEI**
UA1	0.07	0.07	0.03	0.09	<u>0.74</u>	**44.3**
UA2 (PSU)	0.2	0.21	0.15	0.15	<u>0.29</u>	**47.4**
UA3	0.12	0.19	0.25	<u>0.37</u>	0.07	**48.2**

Table 22: Effectiveness Indices of the three universities with different UKTT orientations

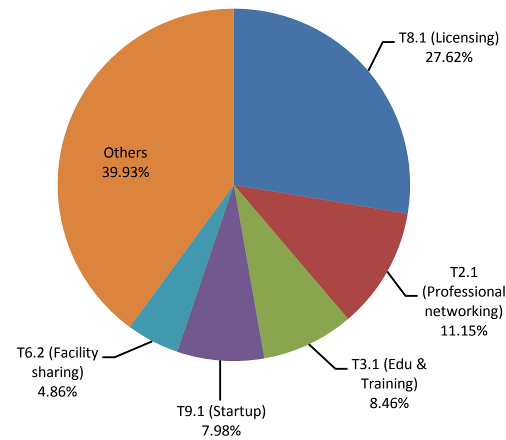
The results in Table 22 reflect the impact of the UKTT orientations of the universities to the final effectiveness indices. UA1 which emphasized heavily on financial return receives lower effectiveness index, while PSU and UA3 receive higher indices due to their more balanced orientations.

In addition to the UKTT Effectiveness Index, we can also know the contributions of the UKTT mechanisms to the Effectiveness Index. Figure 14 shows the five mechanisms that contribute most to the Index. The list and the contributions of these five mechanisms change under different strategic UKTT orientations. Licensing is the highest contributor for UA1 and PSU, but professional networking is for UA3. For university UA1, it contributes 60% to the Effectiveness Index of the university, however only 14.9% in university UA3's Effectiveness Index. Note the difference in the strategic UKTT orientations of these universities. Startup is the second largest contributor for UA1, but not in the top 5 contributors for UA3.

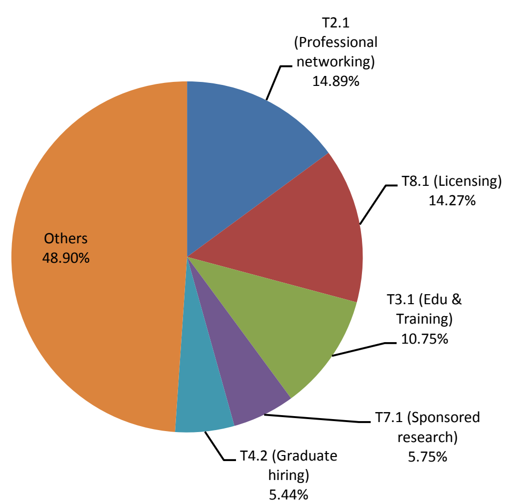
Figure 14: Five mechanisms with highest contributions to the Effectiveness Indices of the three universities



University UA1



University UA2 (PSU)



University UA3

6.2.2 Impact of Strategic UKTT Orientation of the University to the Final Result

In this part we examine the impact of different strategic UKTT orientation of PSU to the final result. The question is "If PSU assumes a different strategic UKTT orientation, how would the results of the model change?". To conduct this experiment, six hypothetical scenarios are set up to represent the university with different UKTT orientations. The first five orientations, or scenarios, represent extreme emphasis on one of the five UKTT objectives. The sixth scenario represents a neutral or balanced prioritization of the objectives.

The six orientations differ from each other in the relative contribution values of the UKTT Objectives with respect to the Mission presented in the following table.

	Objective 1	Objective 2	Objective 3	Objective 4	Objective 5
Orientation 1: "Knowledge"	**0.96**	0.01	0.01	0.01	0.01
Orientation 2: "Innovation"	0.01	**0.96**	0.01	0.01	0.01
Orientation 3: "Economy"	0.01	0.01	**0.96**	0.01	0.01
Orientation 4: "Culture"	0.01	0.01	0.01	**0.96**	0.01
Orientation 5: "Finance"	0.01	0.01	0.01	0.01	**0.96**
Orientation 6: "Balanced"	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**

Table 23: Scenarios of UKTT orientations for PSU

Using the same data set for the UKTT metrics of PSU, the evaluation model returns the final UKTTEI scores presented in the following table.

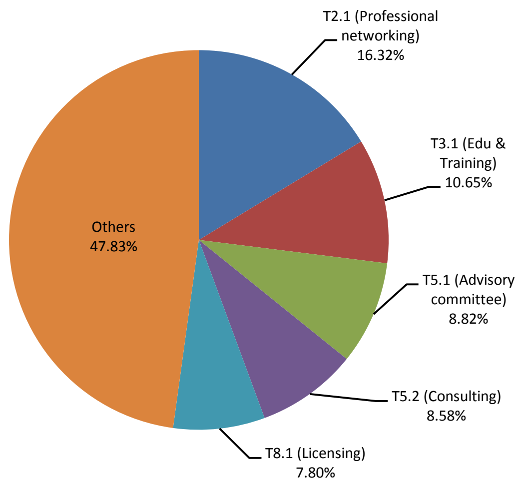
Scenario	UKTTEI
Scenario 1 "Knowledge orientation"	48.0
Scenario 2 "Innovation orientation"	50.2
Scenario 3 "Economy orientation"	51.2
Scenario 4 "Culture orientation"	47.2
Scenario 5 "Finance orientation"	43.0
Scenario 6: “Balanced”	47.9

Table 24: UKTT Effectiveness Indices of the universities with different extreme strategic orientations

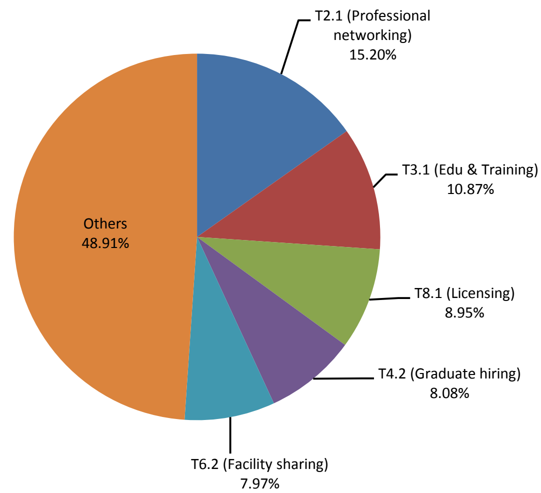
The results show that the orientation toward financial return yields a lower UKTT Effectiveness Index. This observation triggers the question why it is so.

A closer look into the component contribution values of the cases reveals why a finance return orientation results in a lower effectiveness score. It is because UKTT Objective 5 “Financial return” has only two Mechanism Groups, ‘Licensing” and “New Business Creation” contribute to it. Unless the university is outstanding in these two mechanisms, i.e. having very high performance values, it tends to miss out on the contributions by many other UKTT mechanisms. In other words, if a university is strategically oriented towards financial return yet its performance on licensing and startups is just average, it does not have the benefit of supplementary contributions from other UKTT mechanisms to compensate the average performance. That creates an “All or Nothing” position for the university. On the other hand, non-financial return oriented universities enjoy this supplemental benefit from a wide range of UKTT mechanisms, for instance scenario 3. The economic development oriented university receives the highest overall UKTT Effectiveness Index since the strategic objective is supplemented by all ten groups of UKTT mechanisms. Therefore, the UKTT Effectiveness Index is influenced by the number of contribution links from the UKTT mechanism groups to the UKTT objectives. An orientation toward an objective that has more contribution links from the UKTT mechanism groups would yield a higher UKTT Effectiveness Index for the university.

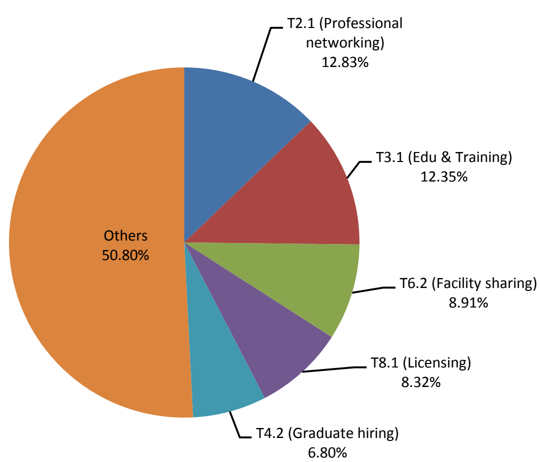
Figure 15 presents the five most contributing UKTT mechanisms to the overall UKTT Effectiveness Index under each orientation. Detail data are provided in APPENDIX J-2. The contribution percentages of the mechanisms to the final UKTTEI are from column 17 in Table 16.



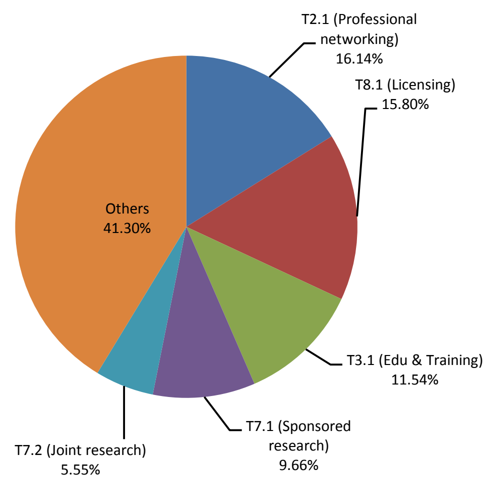
Economy orientation



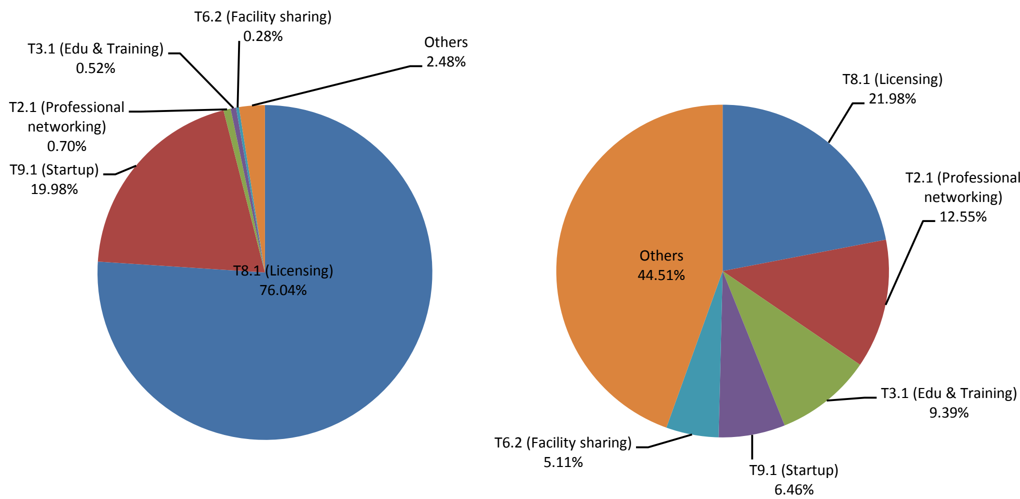
Innovation orientation



Knowledge orientation



Culture orientation



Finance orientation **Balanced orientation**

Figure 15: Percentages of the five most contributing mechanisms to the university's UKTTEI

An examination of the charts in Figure 15 shows the difference between orientations that emphasize on financial return from technology transfer and those that do not. For orientations towards knowledge generation, innovation, economic development, and innovation culture, non legal instruments such as professional networking, education and training for industry, facility sharing, and graduate hiring play a more important role in the final score, though legal instrument like “licensing” still plays a role. Unsurprisingly, the financial return orientation is all about licensing and business startups.

Another observation is while the financial return orientation is heavily skewed towards only two mechanisms, licensing and business startups, the other orientations are more balanced among the UKTT mechanisms. In other words, if the university looks to generate knowledge, innovation, regional economic development, or culture of innovation, the contributions to the overall UKTT effectiveness of the university come from a wide spectrum of activities, including both knowledge transfer and technology transfer means. This is clearly demonstrated in the “Balanced orientation” scenario. If the university is focused on financial return from technology transfer, only licensing and business startups count (Table 25).

	Mechanism ranking									
	1st		2nd		3rd		4th		5th	
Scenario 1 "Knowledge"	T.6.2	0.088	T2.1	0.080	T.8.1	0.077	T.9.1	0.073	T.7.1	0.067
Scenario 2 "Innovation"	T2.1	0.099	T.8.1	0.086	T.6.2	0.082	T.9.1	0.082	T.3.1	0.059
Scenario 3 "Economy"	T2.1	0.108	T.5.1	0.078	T.6.2	0.077	T.8.1	0.077	T.5.2	0.075
Scenario 4 "Culture"	T.8.1	0.143	T.7.1	0.118	T2.1	0.099	T.7.3	0.093	T.7.2	0.071
Scenario 5 "Finance"	T.8.1	0.628	T.9.1	0.339	T2.1	0.004	T.7.1	0.003	T.6.2	0.003
Scenario 6 "Balanced"	T8.1	0.202	T9.1	0.122	T2.1	0.078	T3.1	0.053	T7.3	0.046
Case 1 "UA1"	T.8.1	0.506	T.9.1	0.276	T2.1	0.025	T.7.1	0.020	T.3.1	0.016
Case 2 "PSU"	T.8.1	0.251	T.9.1	0.149	T2.1	0.069	T.6.2	0.047	T.7.1	0.047
Case 3 "UA3"	T.8.1	0.132	T2.1	0.093	T.9.1	0.079	T.7.1	0.072	T.7.3	0.056

Table 25: Top five mechanisms contributing to the mission under different strategic orientations of the universities

6.3 Impact of the Changes in Contributions of the UKTT Mechanism Groups to the Final Result

This analysis investigates how the model result would change if the contributions of the elements on the third level, UKTT mechanism groups, change. Scenarios of different outcomes of the relative contribution values of the ten UKTT Mechanism Groups are identified in Table 26. These scenarios include extreme cases on each of the Groups to explore the boundary of the model, a balanced case and the real case (PSU Baseline model).

The 12 scenarios (cases) in this test are as follows:

	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
Scenario 1 (Information)	**0.91**	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Scenario 2 (Networking)	0.01	**0.91**	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Scenario 3 (Edu&Training)	0.01	0.01	**0.91**	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Scenario 4 (Per.Movement)	0.01	0.01	0.01	**0.91**	0.01	0.01	0.01	0.01	0.01	0.01
Scenario 5 (Consulting)	0.01	0.01	0.01	0.01	**0.91**	0.01	0.01	0.01	0.01	0.01
Scenario 6 (Res.sharing)	0.01	0.01	0.01	0.01	0.01	**0.91**	0.01	0.01	0.01	0.01
Scenario 7 (Research)	0.01	0.01	0.01	0.01	0.01	0.01	**0.91**	0.01	0.01	0.01
Scenario 8 (Licensing)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	**0.91**	0.01	0.01
Scenario 9 (Startup)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	**0.91**	0.01
Scenario 10 (Infrastructure)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	**0.91**
Scenario 11 (Balanced)	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**
Scenario 12 (Baseline)	0.086	0.069	0.080	0.107	0.024	0.079	0.111	0.251	0.149	0.045

Table 26: 12 scenarios of the UKTT Mechanism Groups

APPENDIX J-3 shows the results of this test. As expected, the mechanisms within the Group that were set with the highest relative weights prevail in contributing to the overall Mission. However the distribution of the relative contribution values of the UKTT mechanism groups to the mission is different among the cases as demonstrated in Figure 16. Again, an emphasis on Licensing and Startups makes the distribution heavily skewed towards these mechanisms while emphases on other mechanism groups show wider distributions as exhibited in the Balanced Scenario. This means that no matter how biased the expert judgments of a particular UKTT mechanism group are, the UKTT mechanisms in other groups still contribute to the overall UKTT Effectiveness Index of the university. This effect holds true for all UKTT mechanism groups except for licensing and new business creation groups.

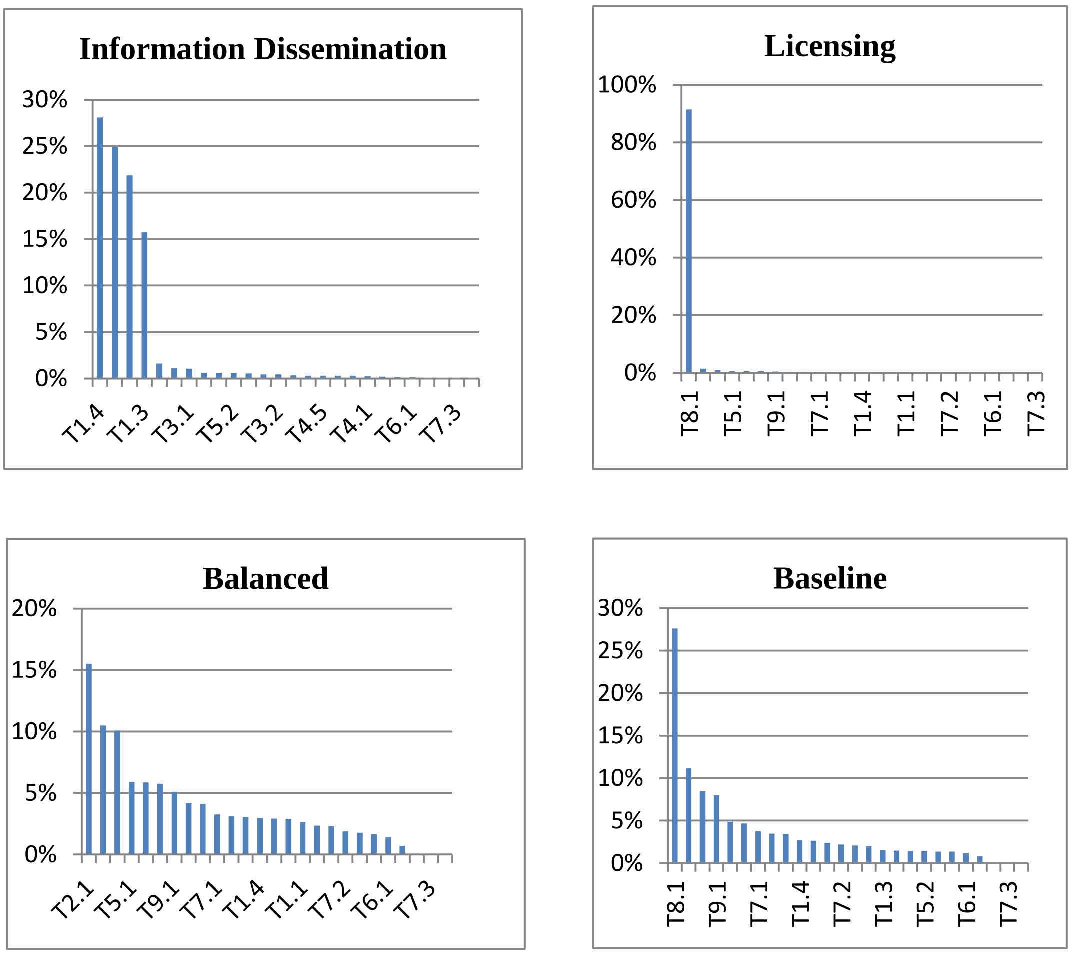


Figure 16: Distribution of contribution values of the mechanisms in some exemplary scenarios

The model also returns the UKTT Effectiveness Indices of the 12 scenarios. They are shown in the following figure.

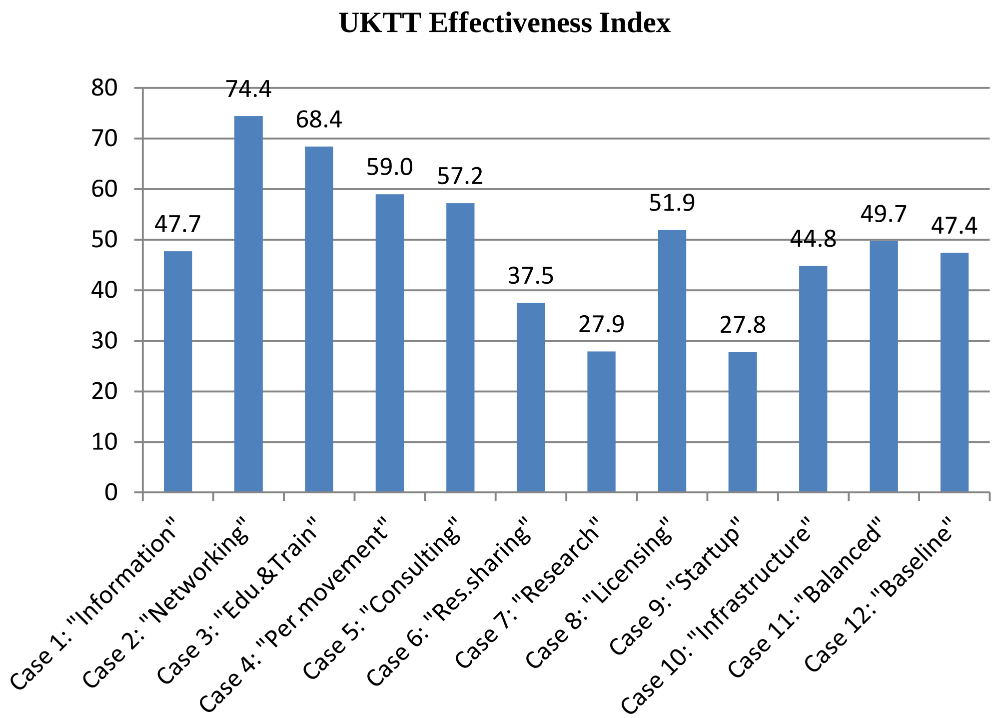


Figure 17: UKTT effectiveness indices of the 12 mechanism group scenarios

All other things being equal, the result shows that the university - PSU in this study – will receive the highest score if the experts judge Professional networking as the only important mechanism group, and lowest scores if they select research or startup group. The explanation is that if the distribution is concentrated on a key mechanism and the university is doing well on that mechanism, meaning its performance value is high, then the UKTT effectiveness index will be high. This is the case of "Professional Networking". Nevertheless if the university is underperforming on that key mechanism its effectiveness index suffers. That is the case of Research and Startup Groups (as indicated by their performance values in Table 16 (see also APPENDIX J-4). If the distribution is more dispersed, this "All or Nothing" effect is lessened. There is a supplementary effect among the UKTT mechanisms in these cases. The Balanced and Baseline scenarios are good demonstrations of this supplemental effect.

The implication of this analysis is that with all other things being equal, any changes in the relative contribution values on the third level of the model will result in the final effectiveness index for the university within the [27.8,74.4] range. That also means the UKTT Effectiveness Index of the university will not exceed 74.4 points given its current performances of the UKTT mechanisms regardless of the experts' judgments of the relative contribution values of the UKTT mechanism groups on the third level of the model. These changes in the relative contribution values of the UKTT mechanism groups may occur in situations such as the research acquiring a different expert group for this level, removing the outliers from the pairwise comparison results, or experts changing their judgments.

6.4 Sensitivity Analysis

This analysis studies the impact of the changes in the input data, i.e. the UKTT metric values of PSU, to the final result of the model. We include the top five UKTT mechanisms that have highest improvement potentials for this analysis, hereafter called the five major mechanisms for improvement. The first part of this section examines the changes in the values of each of the five major mechanisms to the final Effectiveness Index of the university. The second part sees the impact of changes in all five major mechanisms to the final result.

Table 16 indicates the improvement potentials of the UKTT mechanisms. Improvement potential is "room" for improvement of the mechanism, combining a high contribution weights to the mission and a low performance of the mechanisms. The table below presents the top five mechanisms with the highest improvement potentials for PSU.

Mechanism (T)	w(T)	Mechanism Performance (P)	Performance Gap (PG)	Improvement potential (IP)
T8.1 - Licensing	0.251	52	48	12.0
T9.1 - Startups	0.149	25	75	11.1
T7.3 - Research alliances	0.039	0	100	3.9
T6.1 - Materials Transfer Agreements	0.037	15	85	3.2
T7.2 - Joint research	0.034	30	70	2.4

Table 27: Top five mechanisms with highest improvement potentials

Table 27 shows that licensing can potentially contribute an additional 12 points to the UKTT Effectiveness Index for PSU, Startups 11.1 points, and so on.

6.4.1 Changes in Individual UKTT Mechanisms

The analysis is implemented by changing the metric values of the 5 major mechanisms by 5 levels of increments and calculated the resulting UKTTEIs. Each increment of changes is one fifth of the difference between the current values and the values that gives 100 desirability values. For instance, the current number of new startups last year is 2 corresponding to a desirability of 22; the number of new startups of 32 corresponding to the maximum desirability of 100. Then the increment of change for the number of startups metric is (32-2)/5 = 6. This scale of change is applied to all metrics of the five major mechanisms. If a mechanism has more than 1 indicator or metric, all metrics are changed by their respective increments to come up with the changes in the performance values of the mechanisms. Metrics that already have the highest desirability, for instance the average dollar size of a technology license, are unchanged. In this analysis, changes in the metric values and performance value of one mechanism are made at a time, with all others being equal. This allows us to track the sensitivity of the model to a specific UKTT mechanism.

It is predicted that the mechanisms with higher contribution values to the mission would yield more impact on the final result. However the aggregate impact also depends on the desirability values of the metrics, which in turn depends on the desirability curves of the metrics. Therefore, it is necessary to examine the aggregate impact of these factors. Table 28 presents the incremental changes in the values of the metrics of the major mechanisms. The analysis results are provided in APPENDIX J-5 and visually presented in Figure 18.

			Current		Increment 1		Increment 2		Increment 3		Increment 4		Increment 5	
No.	Mechanism (T)	Indicator/Metric	V(E)	D(E)	V(E)	D(E)	V(E)	D(E)	V(E)	D(E)	V(E)	D(E)	V(E)	D(E)
1	T8.1. Licensing	E8.1.1 No. of licenses	22	45	38	72	54	78	70	84	86	90	102	100
		E8.1.2 Average income	450	100	450	100	450	100	450	100	450	100	450	100
		E8.1.3 No. of technologies transferred	8	25	28	58	48	72	68	83	88	89	108	100
2	T9.1. Startups	E9.1.1 No. of startups	2	20	8	70	14	78	20	90	26	96	32	100
		E9.1.2 % faculty involved	3	35	6	62	9	78	12	82	16	92	20	100
3	T7.3. Research alliances	E7.3.1. No. of alliances	0	0	2	56	4	76	6	85	8	92	10	100
		E7.3.2. % faculty involved	0	0	4	68	8	88	12	96	16	99	20	100
		E.7.3.3 No. of companies participating	0	0	3	80	6	90	9	99	12	99	15	100
4	T6.1. MTAs	E.6.1. No. of MTAs	5	15	35	37	65	55	95	74	125	85	155	100
5	T7.2. Joint research	E7.2.1 No. of projects	1	30	17	58	33	74	49	89	65	92	81	100

V(E): actual value of the metric; D(E): desirability value of the metric

Table 28: Changes in the metric values of the five major mechanisms for improvement

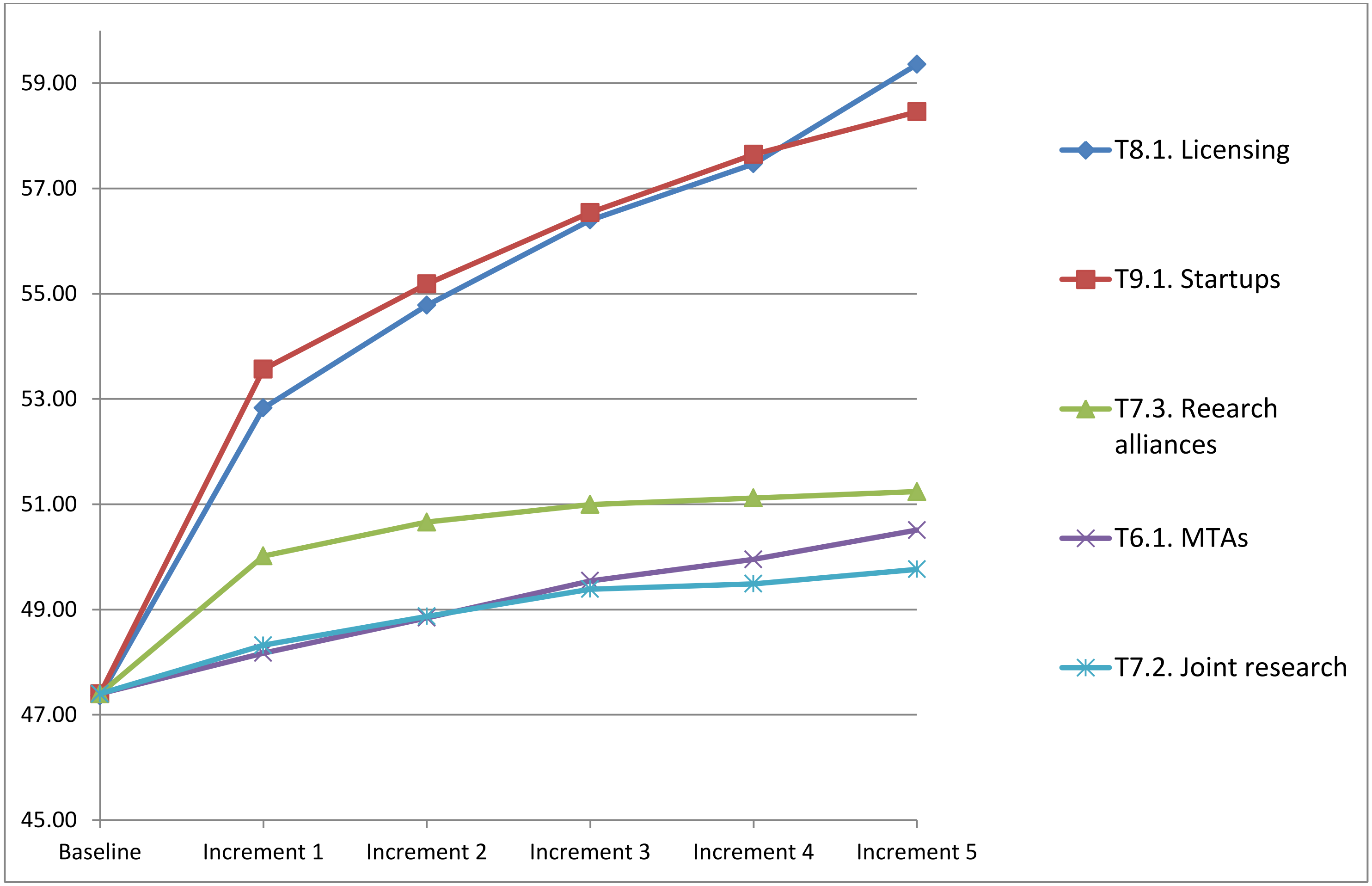


Figure 18: Sensitivity of the final results with respects to changes in the performance values of the UKTT mechanisms

The sensitivity analysis results show that the UKTT Effectiveness Index of the university is more responsive to startups and licensing than to research alliance, MTAs, and joint research mechanisms.

6.4.2 Changes in All Major Mechanisms

This analysis aims to answer the question what if PSU decides to improve all the five major mechanisms. How much the university's UKTT Effectiveness Index would increase if the university achieves the highest desirability values for the metrics of all five major mechanisms?

Table 29 presents the actual values and desirability values of the metrics for current performance and maximum performance of PSU. The result shows that if PSU can achieve the maximum performance of the metrics for all five major mechanisms, the university will increase its UKTT Effectiveness Index significantly by 32.5 points, from 47.4 to 79.9.

Mechanism	Metric	Current performance		Maximum performance	
		V(E)	D(E)	V(E)	D(E)
T8.1. Licensing	E8.1.1 No. of executed licenses	22	45	120	100
	E8.1.2 Average income of a license	450	100	450	100
	E8.1.3 No. of technologies transferred	8	25	110	100
T9.1. Startups	E9.1.1 No. of startups	2	20	30	100
	E9.1.2 % faculty involved in startups	3	35	20	100
T7.3. Research alliances	E7.3.1. No. of research alliances	0	0	10	100
	E7.3.2. % faculty involved in research alliances	0	0	25	100
	E.7.3.3 No. of companies participating in a research alliance	0	0	20	100
T6.1. MTAs	E.6.1. No. of MTAs	5	15	175	100
T7.2. Joint research	E7.2.1 No. of joint research projects	1	30	90	100
	UKTT Effectiveness Index	**47.4**		**79.9**	

Table 29: Actual values and desirability values of the current performance and maximum performance of PSU

CHAPTER 7: MODEL VALIDATION

The developed HDM has been validated on three dimensions: construct, content, and criterion-related.

(1) Construct Validity.

Construct validity refers to the theory-backed concepts used in the model and the quality of the model structure. For this research, all concepts were derived from the literature and common knowledge. The most important element that we want to measure is the effectiveness of university knowledge and technology transfer. The study adopted the organizational effectiveness definition of UKTT which is discussed in the literature. Other concepts such as UKTT Objectives, UKTT Mechanism Groups, UKTT Mechanisms, Indicators and Metrics are summarized from the literature in the field of university knowledge and technology transfer. Desirability values and desirability curves are concepts in the utility theory in decision making. Therefore, all concepts and elements of the HDM are well established and commonly acknowledged.

The structure of the HDM was also verified by the experts involved in the study and independent experts. The conceptual HDM was originally presented in the classes and the PhD Forum at the Department of Engineering and Technology Management, where feedback was received from the participants. The participants were PhD and master students who were trained in decision making courses, so they have an in-depth knowledge of the HDM method. Their inputs were incorporated into the development of the HDM of this research.

(2) Content Validity

Content validity denotes the inclusiveness of the elements in the model. In this study all elements were reviewed and extracted from an extensive review of the literature and public sources. For instance the list of UKTT mechanisms used in this study is a comprehensive collection of UKTT mechanisms mentioned in the literature and other published materials. The content validity was built into the development process of the HDM when experts were asked to verify the relationships between the elements on the lower levels to the elements on the upper levels. The experts determined which elements are included in the pairwise comparison for a particular element on the upper level. For example they specified which UKTT Mechanisms contribute to each of the UKTT Objectives on the upper level. The result is all elements in the model were verified by the experts regarding their relevance to the model.

(3) Criteria-related Validity

The criteria-related validity answers the question: "How much can the evaluation model capture the 'true' UKTT Effectiveness of the university?". There are two main research results that need validated: the evaluation HDM and the UKTT Effectiveness Index. These results were presented to independent experts who were not involved in the research development process to ensure an objective assessment. While these experts generally agree on the evaluation HDM, they expressed concerns about the validity of the final Index due to the assumed data used for the metrics. In addition since this UKTT Effectiveness Index is the first of this kind so there are no references of a "correct" index available for an objective validation.

CHAPTER 8: CONCLUSION

8.1 Summary of the Research.

A Hierarchical Decision Model (HDM) was developed to measure the Effectiveness of University Knowledge and Technology Transfer (UKTT) in this study. There were many attempts to evaluate the effectiveness of UKTT in the literature yet those studies have shortcomings. Some did not look at the problem from the big picture. They only focused on a few legal instruments and ignored the important informal channels to disseminate technological information and knowledge from the university to the public. They suffer from the limited availability of hard data for university technology transfer, for instance AUTM data. This study aimed to approach the problem comprehensively to include all major knowledge and technology transfer mechanisms and examine the contribution of these mechanisms to knowledge and technology transfer effectiveness of the university.

The study adopted an organizational definition of effectiveness, which is the degree of achievement of the university's goal in knowledge and technology transfer. A hierarchy of the problem was constructed with the inputs from the experts in the field. Relative contributions of the elements to the overall UKTT mission of the university were also determined through a judgment quantification process. A new concept of Desirability Curves was applied to convert the actual measurements of the metrics into desirability values as inputs of the evaluation model. This conversion is necessary as it better reflects the usefulness of the numbers in decision making, and it also enables the aggregation of different measurement units. With these inputs the model is capable of producing a composite index to represent the effectiveness of knowledge and technology transfer at universiti(es).

Various analyses were conducted to explore the behavior of the research model, including a disagreement analysis to see the impact of the disagreement of the experts' judgments on the final result, a strategic orientation analysis to explore the implication of the model for universities with different strategic UKTT positions, and a scenario analysis and sensitivity analysis to identify the key UKTT areas for improvement at the university.

The research results show that universities with different strategic UKTT Objective prioritization are influenced by a different set of transfer mechanisms. Particularly there is a contrast between financial return seeking universities and public service oriented universities. The former universities rely mostly on Licensing and Startups, while the latter universities are more balanced on a wide range of knowledge and technology transfer mechanisms, and thus enjoy a supplemental effect among these mechanisms in the overall effectiveness index.

The analysis of the university under investigation, Portland State University, reveals that the university still has much improvement to make in order to increase its UKTT

Effectiveness Index. Licensing, Startups, and Research Alliance are among the important activities that the university should pay attention to.

8.2 Contributions of the Research to the State of Knowledge

The first contribution of this research is to clarify the important concepts and approaches used in the literature on the topic of university knowledge and technology transfer effectiveness. Two main approaches used in prior studies are identified, the innovation diffusion approach and organizational theory approach. Most studies use the first approach while only two papers in the literature, pioneered by Everett Rogers, claim the second. A remarkable observation about the studies taking the innovation diffusion approach is that they do not clearly define what effectiveness is, so the evaluation approaches were loosely designed. On the other hand, the organizational theory approach gives a very clear definition of UKTT effectiveness, one that facilitates a sound evaluation method for the study. Unfortunately the two papers that adopted this definition in the literature failed to actually measure what is defined due to the limited data source and unsuitable research method. The categorization set forth by this research gives guidance for future research in defining the problem appropriately. The current study adopts the organizational effectiveness approach and becomes the third example in the literature on this approach for future studies.

The second contribution of this study to the literature is the expansion of the use of new research methods on the topic. Prior research is limited to a few traditional research methods such as material review, discussion, statistical analysis, etc. They only used hard data from a few source sources, mainly AUTM, with common metrics such as the number of licenses, number of startups, licensing revenues, and research expenditures. This limitation in fact put a curb on the freedom and diversity in academic research of the topic. The result is there are not many breakthrough research ideas or approaches to the extent that a prominent researcher recommended that future research should look in data sources other than AUTM and NSF used in this study, and take the role of university administrators into the examination of university technology transfer effectiveness, (E. Rogers et al., 2001), and that the technology metrics should be shifted toward a more balanced metric focused on the mission of the research institution (Sorensen and Chambers, 2007) This study accomplished these quests by introducing HDM as a research method for the problem. By applying a judgment quantification method the study was able to draw upon a new source of data, expert judgments, to address the problem from a new perspective and come up with completely new results. The novel approach used in this study has shed new light on the topic and may open a new stream of research in the literature.

Most importantly this study answers one of the most critical research questions raised in the literature regarding evaluating UKTT effectiveness: “Can a measure of technology transfer effectiveness be developed for US research universities?” ([49] [73]). The study successfully developed a research model to address this question not only to research universities in the US, but to universities anywhere. The measure is represented by a UKTT Effectiveness Index which is a quantitative indicator of the effectiveness of the university in transferring knowledge and technology to society. The model is robust enough to identify strategic areas for the university to improve its knowledge and technology transfer. In addition it enables comparison the UKTT effectiveness among the universities so that individual universities can identify the benchmarks for their performances. It is the first time that the roles of various knowledge and technology transfer mechanisms are manifested by concrete numbers. This is also the first study in which a university's priority of objectives with respect to the economic development mission is quantified with numbers and the relationships between the strategic UKTT orientation of the university and the key UKTT areas are demonstrated.

Last but not least, the approach introduced by this study can be applied to similar research in related fields, including government technology transfer, private sector technology transfer, and international technology transfer.

8.3 Implications of the Study

The study has a two-pronged implication for academic research and practitioners in academic knowledge and technology transfer. For the UKTT research community this study set an example for exploring new research methods and data sources to approach the evaluation problem. Other researchers can employ the same method used in this study, or further develop the research method, to investigate the problem in different settings.

For UKTT administrators, managers, and practitioners this research provides them with a new way to assess their knowledge and technology transfer activity. It is hoped that the study sheds new understanding for the university administrators and technology transfer managers about the wide boundary of the knowledge and technology transfer activities taking place at their institutions. This boundary should not be viewed as confined to a few transfer mechanisms but rather encompassing the many more subtle and informal channels to transfer both knowledge and technologies from the university to the outside world. Therefore, a comprehensive evaluation of the activity entails the consideration of all these important transfer mechanisms to fully account for the impact of research and knowledge and technology transfer from universities. With this study, policy makers see the large and complex problem of measuring UKTT effectiveness broken down into a well-structured hierarchy of objectives and specific transfer mechanisms and the relationships among them. They can now see the big picture of academic knowledge and technology transfer.

Universities' research expenditures have been increasing at impressive rates in recent years, and there is rising compelling concern about the effectiveness of those large expenditures. This study will help university administrators answer this important question. Unlike prior evaluation methods, this evaluation model gives them a concrete number, the UKTT Effectiveness Index, to have a grasp of the situation. It is much better for people to work with specific numbers than qualitative statements. These quantified results allow convenient comparisons between the university and its peers, and identifying the areas where the university needs to improve. With this evaluation model UKTT practitioners will for the first time see their priorities worked out in specific numbers, i.e. the relative weights, and the dynamics in the contributions of the UKTT mechanisms to the overall performance of the university. These results are useful information for decision makers to plan and manage knowledge and technology transfer activities at their institutions.

The research approach in this study can be applied to other institutional levels or different types of organizations involving technology transfer. For example, it can be modified to evaluate the effectiveness of a Technology Transfer Office at a university. In this case, the top level of the HDM is the mission of the office, and the transfer mechanisms and metrics are those most appropriate to their works. Another example is AUTM. The Association can conduct a comparative study among its members for ranking purposes, for instance. In this case the organization will develop a common hierarchical model and weights for its members, or different classes of members. The evaluation approach introduced in this research facilitates flexible applications in many circumstances.

In order to conduct a study of this comprehensiveness, it is recommended that universities, or any organization that wants to apply this research approach, set up a university-wide tracking systems of the UKTT mechanism metrics. The university can decide what UKTT mechanisms are important to its mission and what metrics to use for the mechanisms, then set up a tracking system to collect data of these metrics on a periodic basis. An important note is the more knowledge and technology mechanisms are included in the evaluation, the more comprehensive the evaluation model is, and the more accurate the data that are made available the more reliable the final results are.

8.4 Limitations of the Study.

The evaluation model is presented in this study as a novel and robust model to evaluate university knowledge and technology transfer, yet not without caveats. As in any subjective judgment quantification studies, the results of the research largely depends on the makeup of the expert groups involved. Experts are independent individuals and they may have conflicting opinions about the same problem. This study could not engage the most suitable experts for its purpose due to the lack of connections and the willingness to participate of the invited persons. However it is impossible to eliminate the subjectivity in a research of this nature. Even if the best experts are recruited according to the selection criteria described in this report their judgments are still considered relative.

Another shortcoming of the study is the incomplete data set of the metrics. Unlike most prior research that is based on available data only, this research ventured into areas where data have not been reported at the universities or by any sources. As a result this research assumes many estimated figures to demonstrate the model. That is one of the reasons why validation of the model results is difficult. With a complete and updated set of actual values of the UKTT mechanism metrics the final results would have been more justifiable.

Another limitation of the research is that it did not include all departments that are possibly doing research at the university. Even though the study examines the major science, technology, science, and math departments it does not represent the entire university.

It would have added much more information to the results if the study had included a comparative analysis among a group of universities to see how a particular university ranks in the group in terms of UKTT effectiveness. Due to time limits, this study only investigates a university's UKTT effectiveness, although it provides an analysis on the different strategic UKTT orientations of the universities. Nevertheless, the procedure to evaluate the UKTT effectiveness of a group of universities is laid out in this study.

8.5 Future Work

Any interested individual may try to replicate this research in a better controlled study. In such a controlled study, the best experts would be engaged, and the model elements including UKTT mission, objectives, mechanisms and mechanisms groups, indicator and metrics, and desirability curves would be refined. Coupled with a complete set of updated data obtained from the institutions, the model would give evaluation results with greater validity.

Other study may try to apply the model to the entire university to include all departments that transfer any type of new knowledge and technologies generated at the university to the external environment.

It would enhance the sensitivity analysis of the results to conduct a simulation. In the simulation, many variables could be changed simultaneously. Decision makers at universities may be interested in identifying key UKTT areas to their institutions and carry out a simulation model to see how the key UKTT areas impact the overall performance of the institution.

As mentioned earlier, future work from this study can include an evaluation and comparison of a group of research universities. This study is of particular interest to the university administrators including university presidents, board of directors, vice president in charge of research and technology transfer, etc. These people are the policy makers at the universities and it is in their interest to know how well the university is doing as compared to their counterparts, as well as how to better allocate resources to improve the effectiveness of the activity.

One might be interested in applying this model in another setting such as government labs or private labs. Others might apply it in another country or conduct a cross-country evaluation. Another possibility is to implement a longitudinal study to examine the effectiveness of an organization over a period of time.

This study identified the strategic UKTT mechanisms to the university which could be the first step for a resource allocation study. For example the university may examine which course to take, increasing the number of students with industry internships or increasing the number of research alliances, from a resource point of view. Even though research alliance contributes more to the overall UKTT effectiveness of the university, improving the interns may be more practical to achieve.

Another possible research direction is to evaluate the economic returns of all the knowledge and technology mechanisms identified in this study and determine the total returns on investment – ROI - of the research expenditures at a university. The study has pointed out that licensing income or start-up revenues are not the only returns from the expenditures that universities have invested in their research. Researchers need to take into consideration the non-financial returns that all other knowledge and technology transfer means bring in as a result of research. This task is very challenging, but it will address an important question both in the literature and practice.

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APPENDICES

APPENDIX A: UKTT MECHANISMS AND ASSOCIATED INDICATORS PRESENTED IN THE LITERATURE

UKTT means	Indicators
Information transfer	Website; Personal contacts; direct mailing / fax; Trade shows; meetings; inventor contacts. [17]
University technology showcase	n/a
Scientific publications	Number of publications. [21] Impact (citations). [21] Activity (focus). [21]
Professional publications and reports	number of reports delivered. [5]
Conferences	number of conferences, workshops, symposia, and joint seminars conducted. [5]
Workshops, classes	number of workshops, symposia, and joint seminars conducted. [5]
Knowledge access	citation analysis, research exemptions, humanitarian use exceptions, alliance management, exclusivity shifting, capacity building in developing regions, open source business modeling and patent pooling or bundling. [71]
Informal meetings/contacts	number of contacts between parties at each stage of the interaction; organizational level of contacts; duration/intensity level of contacts (brief conversation, meetings, etc.); time to fruition of interactions (days, weeks, years to research agreements or research results); Levels of each organization involved in a given interaction. [5]
Presentation of research	n/a
Industry sponsored meetings	n/a
Friendship networks	n/a
Professional networks	n/a
Alumni societies	n/a
Informal grouping of companies	n/a
Advisory boards	Formation of Advisory Boards and degree of formalizing interaction mechanisms. [5]
Membership in tech transfer organizations	n/a
University center or industrial liaison units	n/a
Industrial fellowships	number of fellowships established. [5]

Graduate recruiting/hiring	Number of graduate students hired by industry. [5]
Training for students	
Training and education of employees	number of training programs established
Common courses	Number of industrial researchers as guest lecturers at university. [5]
Incorporation of research findings into courses	n/a
Providing scholarships	n/a
Sponsoring of education	n/a
Internships	n/a
Co-supervising	n/a
Doctoral students	n/a
Personnel exchange	n/a
Dual appointments	n/a
Industry grants, gifts to university	amounts of money changing hands. [5]
Technical assistance	Number of technical problems solved. [5]
Consulting services	number of faculty hired as consultants to industry. [5]
Prototype development, fabrication, testing	n/a
Industrial associates	n/a
Use of university facilities	n/a
Sharing of facilities	n/a
Industry funded facilities	n/a
Patents	Number of patents. [21] Impact (citations). [21] Median age of patents. [21]
Co-patenting	Number of patents, inventions, and innovations in joint effort . [5]
Copyright	n/a
Licensing	Royalties / license fees generated. [17] Sponsored research funds; [17] Number of licenses /options signed. [17] Number of patents awarded; [17] Number of inventions commercialized. [17]
Follow-up consulting service to a license	n/a
Multi-discipline research groups	n/a
Cooperative research projects	Number of joint projects established. [5]
Cooperative research programs	Degree of institutionalization of contacts (multiyear agreements, permanent committees formed, etc.). [5]
Research consortia / alliances	number of consortia developed. [5]

University research centers	Average annual budget; average number of academic departments involved; average number of staff members; average number of funding sources; average age of the research center; percentage of research centers saying external funding is a reason for founding; percentage of research centers saying publications are a means of technology transfer; percent of research centers with a spin-off. [48] Major tech transfer mechanisms employed; formal tech transfer organization; reduction of industry risks, reduction of research center's risks; availability of resources; advertising the technology, originality of technology. [51] Level of industrial support for research centers and programs. [5]
Research parks, science parks, technology parks	Number of new products; number of patents; number of copyrights. [77] number of third party involvements (government, venture capital firms); degree of institutionalization of relations; level of continuing (multi-year) industrial support; level of satisfaction with interaction. [5]
Joint ventures of R&D	n/a
Spin-offs	Number of spin-off enterprises. [5]
Incubators	Average incubator size (sq. ft). [80] Average number of tenants. [80] Average number of tenant employees. [80] Number of graduates per year. [80] Tenant failure rate (%).[80] Average graduate employment. [80] Firms remaining in community (%). [80] Program growth and sustainability: rentable space, budget support growth. [79] Tenant firm's survival and growth: graduate rate, sales and employment growth. [79] Contributions to sponsoring university's mission: public image, number of faculty entrepreneurs/student trainees/employees, adverse impact on university's environment Community related impacts: income, jobs, and other qualitative measures. [79] Effectiveness of management policies and practices: goals, structure, and governance; Financing and capitalization; Operational policies; Target markets. [79] number of third party involvements (government, venture capital firms). [5]
TTO	Number of invention disclosures; number of US patent applications files; number of technology licenses and options executed; the number of technology licenses and

	options yielding income; number of start-up companies spun off the university (based on a technology licensed by the university's TTO); total amount of technology licensing royalties earned per year. [49] [73]
Stimulating entrepreneurship	n/a
Technology commercialization intermediaries	n/a
Proof of concept center	n/a
Participation in economic development programs	n/a
Serendipity	n/a
Knowledge Integration Community	n/a

APPENDIX B: LITERATURE PAPERS RELATED TO UKTT

No	Article	Topic	Research method	Level	Comment
1	A. Link and D. Siegel, 2005.	evaluating the impact of organizational incentives on the effectiveness of University/Industry technology transfer	QN: econometric analysis	TTO	claims to evaluate the impact of organizational incentives on the effectiveness of University/Industry technology transfer while in fact measures the productivity of licensing activity of the TTO in terms of outputs over inputs
2	A. Link and J. Scott, 2005.	spin-offs companies from university research parks	QN: Tobit estimates	university park	discusses only spinoffs as opposed to a wider spectrum of TT mechanisms
3	A.N. Link, D.S. Siegel, and B. Bozeman, 2007.	exploring the level of engagement of university researchers in informal TT channels	QN: regression analysis	researcher	focused on the informal group of UTT mechanisms
4	A. Agrawal, 2002.	knowledge transfer channels at MIT	QL: survey/interview	researcher	only investigates patents and start-ups
5	A. Warren, R. Hanke, and D. Trotzer, 2008.	proposal of new models for university technology transfer to improve the effectiveness of UTT.	QN: regression analysis	TTO	uses data from AUTM which involve patents, licenses, spin-offs only as opposed to a wider range of TT mechanisms
6	A. Nosella and R. Grimaldi, 2009.	academic spin-offs in Italy.	QN: regression analysis	TTO	discusses only spinoffs as opposed to a wider spectrum of TT mechanisms
7	A.K. Agrawal, 2001.	literature review on University to industry knowledge transfer	QL: material review	general	does not include evaluation studies
8	Alf Steinar Sætre, Joel Wiggins, Ola Thomas Atkinson, and Beate Kristin Ellerås Atkinson, 2009.	a comparative study on university spin-offs among Norway, the United States, and Sweden	QL: case studies, interview	firm	discusses only spinoffs as opposed to a wider spectrum of TT mechanisms

9	B. Carlsson and A.-C. Fridh, 2002.	the role of TTOs at leading US research universities	QN: survey, statistical analysis	TTO	limited to the scope of responsibility of the TTO, thus does not cover the broader spectrum of research output transfer
10	C. Grimpe and H. Fier, 2009.	comparison of the informal university technology transfer in the US and Germany	QN: probit regression	researcher	examines only informal TT activities as opposed to a wider spectrum of TT mechanisms
11	C. Grimpe and K. Hussinger, 2008.	The relationship between formal and informal UTT mechanisms to firm's innovation	QN: regression analysis	firm	presents a fairly comprehensive list of knowledge and technology transfer mechanisms, yet without metrics
12	D.R. Trune and L.N. Goslin, 1998.	Profitability analysis of university technology transfer programs	QN: profit/loss analysis	university	profit/cost data were extracted from AUTM, which might not represent all direct and indirect benefits and costs of the TT programs.
13	D. S. Siegel, D. A. Waldman, L. E. Atwater, and A. N. Link, 2005.	factors impeding UTT at five US research universities	QL: interview and descriptive statistics	university	TT effectiveness adopting innovation diffusion theory approach by identifying factors influencing the TT process
14	E. Rogers, 2001.	Lessons learned about UTT in New Mexico state.	QL: material review	university	presents various but not comprehensive UTT mechanisms, particularly the informal channels
15	E.M. Rogers, J. Yin, and J. Hoffmann, 2000.	Measuring the university/industry TT effectiveness	QN: Correlation analysis	TTO	TT effectiveness are measured based on six steps of the TT process proposed by the authors, which revolve patents, licenses, start-ups. This approach might not reflect the more comprehensive TT spectrum at research universities.
16	E. Rogers, B. “J” Hall, M. Hashimoto, M. Steffensen, K.L. Speakman, and M.K. Timko, 1999.	Effectiveness of university research centers at University of New Mexico	QL: Interview/correlation analysis	research center	Effectiveness is defined as the degree to which an organization fulfills its objectives. However the ratings are subjectively done by the authors based on their interviews with the research centers
17	E. Geisler and A. Rubenstein, 1989.	Major issues in UTT literature	QL: material review	researcher	does not apply any specific research methodology
18	J. Bercovitz and M. Feldman, 2005.	the role of universities in system of innovation	QL: material review	university	does not apply any specific research methodology

19	J. Friedman and J. Silberman, 2003	Determinants of university technology transfer	QN: regression analysis	university	the unit of analysis is the university, yet data used are from AUTM. This may not reflect the whole picture of research output transfer
20	J.A.T. Sorensen and D.A. Chambers, 2007.	A need for a more balanced TT performance metrics including both monetary and non-monetary measures	QL: material review	TTO	Proposing just one new TT metric: access metric.
21	M. Feldman, I. Feller, J. Bercovitz, and R. Burton, 2001.	Review the technology transfer activities at leading research universities	QL: material review	university	based on only a small group of TT indicators
22	M. Decter, D. Bennett, and M. Leseure, 2007.	Comparing UTT practices in USA and the UK	QN: survey	TTO	does not consider specific TT mechanisms
23	N. Baldini, 2006.	literature review on university patenting and licensing activity since 1980	QL: material review	general	discusses only patenting and licensing as opposed to a wider spectrum of TT mechanisms
24	P. H. Phan and D. Siegel, 2006.	Literature review of university entrepreneurship	QL: material review	general	Limited to only new firm formation as a technology commercialization method
25	P. Deste and P. Patel, 2007.	knowledge transfer mechanisms through which academic researchers in UK interact with industry and factors that influence the researchers' engagement in a variety of interactions.	QN: correlation analysis	researcher	does not discuss the transfer mechanisms or channels in depth
26	R. Bekkers and I. Bodasfreitas, *2008.*	impact factors of channels for knowledge transfer between university and industry in the Netherlands	QN: cluster analysis / binary logistic model	researcher	based on subjective ratings of respondents without employing any judgment quanfitication method
27	R. Brennenraedts, R. Bekkers, and V. Verspagen, 2006.	which knowledge transfer channels are more preferred by the academic researchers	QN: cluster analysis	researcher	only looks at a subset of Research output transfer mechanisms
28	R. Jensen and M. Thursby, 2001.	Characteristics of university technology licencsing	QL: analytical theorem development	TTO	discusses only licensing as opposed to a wider spectrum of TT mechanisms

29	R. Oshea, T. Allen, A. Chevalier, and F. Roche, 2005.	relationship between resources and number of university spin-offs	QN: econometric model	university	discuss only spinoffs as opposed to a wider spectrum of TT mechanisms
30	R. DeVol et al., 2006.	Analysis and comparison of biomedical UTT in major global markets	QN: regression / simulation	university	weights assigned to the indexes subjectively by researchers
31	R. Phillips, 2002	the effectiveness of technology business incubator as technology transfer mechanism.	descriptive statistical analysis	Incubator	effectiveness of technology business incubators are not specifically defined and measured by performances of the mechanism.
32	R.A. Lowe, 2006	decision making of university inventors in starting a new spinoffs	QN: econometric model development	researcher	discusses only spinoffs as opposed to a wider spectrum of TT mechanisms
33	R.P. O'Shea, T.J. Allen, K.P. Morse, C. O'Gorman, and F. Roche, 2007.	success factors of spinoff activities at MIT related nature of the drivers of spinoff activities	QL: material review / case study	university	discusses only spinoffs as opposed to a wider spectrum of TT mechanisms
34	S. Mian, 1997.	assessment of university technology business centers	QL: material review	Incubator	discusses only incubators as opposed to a wider spectrum of TT mechanisms
35	S. Arvanitis, N. Sydow, and M. Woerter, 2007.	the impact of different groups of university KTT activities on the innovation performance of firms in Switzerland	QN: probit model;nearest neighbor matching;caliper matching method	firm	covers most Knowledge Transfer activities but leaves out patenting, spinoffs
36	S. Mosey, A. Lockett, and P. Westhead, 2006	Fellowship programmes as university technology transfer	QN: survey, descriptive statistics	researcher	discusses only one TT initiative as opposed to a wider spectrum of TT mechanisms
37	T. Thune, *2009.*	The role of doctoral students in exchanging knowledge and technology from universities to industry	QL: material review	researcher	discusses only doctoral students as opposed to a wider spectrum of TT mechanisms

Note: QL: qualitative research method; QN: quantitative research method

APPENDIX C: EXPERT GROUPS

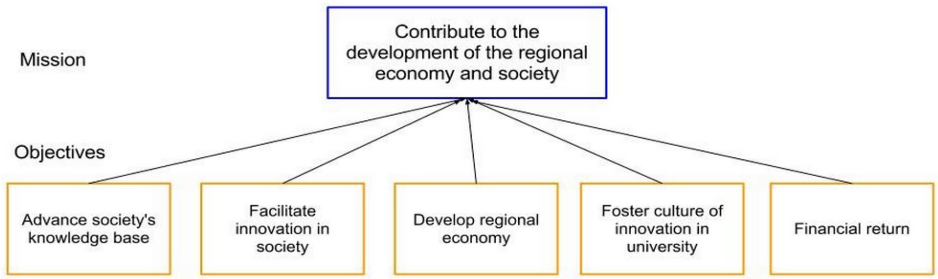
No.	Expert code	Position	Location	Verification of UKTT objectives	Pair wise comparison of UKTT objectives	Verification of UTTK mechanism groups	Pairwise comparisons of the UKTT mechanism groups	Pair wise comparison of the UKTT mechanism and indicators	Desirability of UKTT mechanism metrics
1	UA1	Vice President for Research	USA	●	●				
2	UA2	Vice President for Research and Strategic Partnerships	USA	●	●				
3	UA3	Vice Chancellor for Research and Economic Development	USA	●	●				
4	AR1	Faculty, College of Urban Planning and Public Affairs.	USA			●	●	●	●
5	AR2	Faculty, Department of Management, College of Business	USA			●	●		
6	AR3	Faculty, School of public policy	USA			●			
7	AR4	Faculty, College of Business	USA			●		●	●
8	AR5	Faculty, College of Business	Europe			●		●	●
9	AR6	Faculty, Department of Public Administration and Policy	USA			●	●	●	●
10	AR7	Faculty, School of Business	USA			●			
11	AR8	Faculty, School of Business	USA			●	●	●	●
12	AR9	Faculty, Interim Dean of Business School	USA			●	●	●	●
13	AR10	Faculty, Institute of Management	Europe			●	●	●	●
14	AR11	Faculty,Management	Europe			●	●	●	●
15	AR12	Faculty, Entrepreneurship	Europe			●		●	●
16	AR13	Faculty, Senior Reseacher, Triple Helix Association	USA	●					
17	AR14	Faculty, School of Business	USA			●	●		
18	AR15	Faculty, Department of Educational Leadership	USA			●	●	●	●
19	AR16	Faculty, Innovation Management	Europe			●	●	●	●
20	AR17	Researcher, Center for Innovation	Europe			●	●	●	●
21	AR18	Faculty, Strategy & entrepreneurship	USA			●	●	●	●
22	AR19	Faculty, Economic Geography	Europe			●	●	●	●

23	AR20	Senior researcher, School of Management	USA			●			
24	AR21	Faculty, Innovation Management	Europe			●	●	●	●
25	AR22	Researcher, Triple Helix Association	South America			●		●	●
26	TM1	Director, Entrepreneurship Center	USA			●	●		
27	TM2	Director of Licensing; Center for Technology Transfer and Commercialization	USA					●	●
28	TM3	Executive Director of Innovation & New Ventures	USA			●		●	●
29	TM4	Assistant Vice President for Innovation	USA			●			
30	TM5	Director of Innovation and IP	USA			●	●		
31	TM6	Executive Director, Center for Technology Enterprise and Commercialization. Vice Provost for Tech Transfer & Economic Development	USA	●		●	●	●	●
32	TM7	Director of Technology Transfer	USA					●	●
33	TM8	Presidential Chair of Entrepreneurship Center	USA	●					
34	TM9	Director, Entrepreneurship center	USA	●					
35	TM10	Licensing director	USA					●	●
			Total	**7**	**3**	**26**	**17**	**21**	**21**

UA: university Administrator; AR: Academic Researcher; TM: Technology Transfer Manager

APPENDIX D: RESEARCH INSTRUMENTS

APPENDIX D-1: RESEACH INSTRUMENT 2.1 – VERIFYING THE LINKAGES BETWEEN THE UKTT OBJECTIVES AND THE MISSION



Please identify the university knowledge and technology transfer objectives that, in your judgment, contribute to the economic development mission of universities.

Instructions:

- Please click "Yes" if you think that the specific UKTT objective contributes to the stated mission
- Please click "No" if you think that the specific UKTT objective does not contribute to the stated mission
- If you think of other UKTT objectives that are not listed below or have any comments/notes, please add them in the space provided

OBJECTIVE 1: ADVANCE SOCIETY'S KNOWLEDGE BASE

Yes No

*

OBJECTIVE 2: FACILITATE INNOVATION IN SOCIETY

Yes No

*

OBJECTIVE 3: DEVELOP REGIONAL ECONOMY

Yes No

*

OBJECTIVE 4: FOSTER CULTURE OF INNOVATION IN THE UNIVERSITY

Yes No

*

OBJECTIVE 5: FINANCIAL RETURN

Yes No

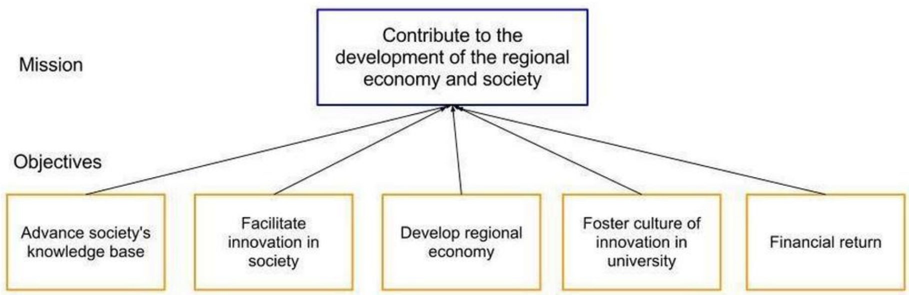
*

Please use the following block for your comments, and for suggesting additional UKTT objectives, if any.

APPENDIX D-2: RESEACH INSTRUMENT 2.2 – QUANTIFYING THE CONTRIBUTION VALUES OF THE UKTT OBJECTIVES WITH RESPECT TO THE UKTT MISSION

Research Instrument 2.2 - Quantifying the relative importance of UKTT objectives with respect to UKTT Mission.

The objectives of University Knowledge and Technology Transfer (UKTT) which contribute to the achievement of the university's mission in knowledge and technology transfer have been verified by a group of experts . They include five UKTT objectives described as follows:



Objective 1 vs. Objective 2

O1: Enhance knowledge base of society — O2: Facilitate innovation in society

	1	11	21	30	40	50	60	70	79	89	99
Importance with respect to UKTT mission											

Objective 1 vs. Objective 3

O1: Enhance knowledge base of society — O3: Develop regional economy

	1	11	21	30	40	50	60	70	79	89	99
Importance with respect to UKTT mission											

Objective 1 vs. Objective 4

Objective 1: Enhance knowledge base of society — Objective 4: Foster innovation culture in university

	1	11	21	30	40	50	60	70	79	89	99
Importance with respect to UKTT mission											

Objective 1 vs. Objective 5

Objective 1: Enhance knowledge base of society — Objective 5: Financial return

	1	11	21	30	40	50	60	70	79	89	99
Importance with respect to UKTT mission											

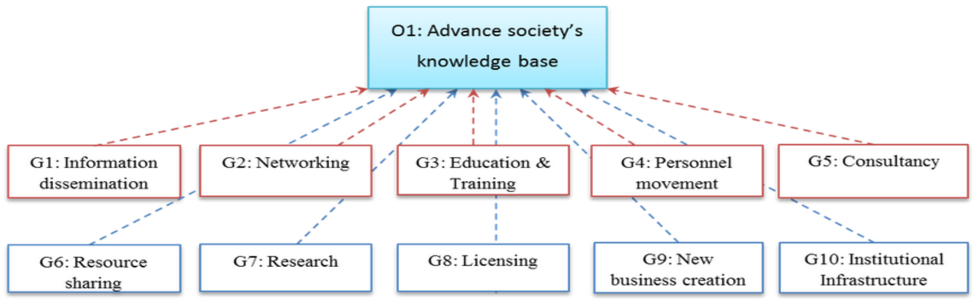
APPENDIX D-3: RESEACH INSTRUMENT 3.1 – VERIFYING THE LINKAGES BETWEEN THE UKTT MECHANISM GROUPS OBJECTIVES AND THE UKTT OBJECTIVES

A

Research Instrument 3.1 - Determining the linkages of the groups of mechanisms to the UKTT Objectives

OBJECTIVE 1: ADVANCE SOCIETY'S KNOWLEDGE BASE

An objective of university knowledge and technology transfer (UKTT) is transferring new scientific knowledge to the society so that the new knowledge can be widely accessible and used by the general public. The advancement of the knowledge base of the society may benefit individuals as well as business entities within that society. This objective has been verified by a group of experts which includes the Vice Presidents for Research at some universities. The next step in developing the HDM model is to determine which groups of UKTT mechanisms may be employed by universities toward the achievement of this objective. It is also the purpose of this instrument.



The UKTT mechanisms or means proposed in this instrument are drawn from an exhaustive review of the literature, and are presented in ten distinct groups. A brief summary of the groups is given below:

G1: Information dissemination
This group consists of channels that help distribute the information about knowledge and technologies to the target audience or the public. Examples: informational materials (websites, brochures, newsletters, etc.), industry presentations, technology expositions, publications, conferences, seminars, workshops, etc.

G2: Networking
This group consists of ways that university researchers connect with each other. It has been proved that this is an effective method researchers frequently use to exchange information. Examples include professional and alumni organizations.

1.1 Group 1: INFORMATION DISSEMINATION MECHANISMS
- Yes
- No

1.2 Group 2: NETWORKING MECHANISMS
- Yes
- No

1.3 Group 3: EDUCATION & TRAINING MECHANISMS
- Yes
- No

1.4 Group 4: PERSONNEL MOVEMENT MECHANISMS
- Yes
- No

1.5 Group 5: CONSULTANCY MECHANISMS
- Yes
- No

1.6 Group 6: RESOURCE SHARING MECHANISMS
- Yes
- No

1.7 Group 7: RESEARCH MECHANISMS
- Yes
- No

APPENDIX D-4: RESEACH INSTRUMENT 3.2 – QUANTIFYING THE CONTRIBUTION VALUES OF THE UKTT MECHANISM GROUPS WITH RESPECT TO THE UKTT OBJECTIVES

Research Instrument 3.2: QUANTIFYING THE CONTRIBUTIONS OF UKTT MECHANISM GROUPS TO UKTT OBJECTIVES

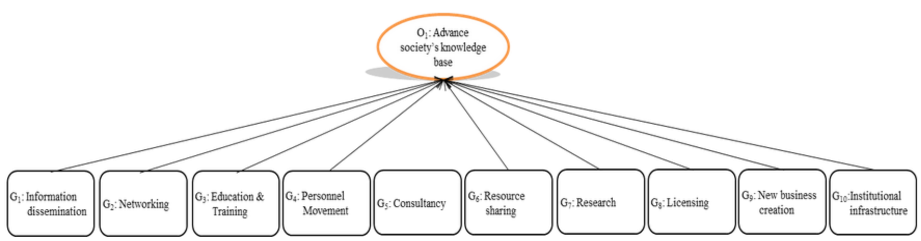
In the previous research instrument, the experts identified the linkages between the groups of university knowledge and technology transfer (UKTT) mechanisms and the UKTT Objectives. Linkages verified by 80% or more of the experts were retained in the model. Please click here if you would ilke to read the description of the UKTT objectives and mechanism groups.

This research instrument is for the experts to express their judgments about the relative importance of the groups with respect to the UKTT objectives. Data provided by the experts will be processed using the HDM© software to calculate the relative importance of each group of UKTT mechanisms to the speficic Objectives.

Instructions:
In this method, the expert will allocate a total of 100 points to pairs of UKTT mechanim groups in proportion of their relative importance to the stated UKTT objective. Two groups are compared against each other at a timed. Minimum value assigned to a group is 1.

You can drag the slider left or right to express your judgments, or click at the desired value on the scale. The value on the slider indicates the value assigned to the first group. For example: If group A is ¼ as important as group B, move the slider so that the value indicates 20, or click at 20. If A is 3 times as important as B, A gets 75 points, (and thus B gets 25 points). If the importance of A and B are the same, both get 50 points. This is the case regardless of whether both are extremely important, mildly important or equally unimportant.

PART1: OBJECTIVE 1

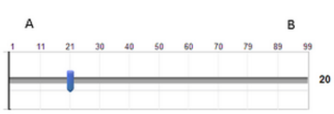


Please click here if you would like to see the description of the UKTT objectives and mechanism groups.

There are 32 comparisons in this part. Please give your judgment for each pair of the mechanism groups below with respect to the UKTT objective 1. The question is "how important is a UKTT mechanism group in contributing to objective 1 relative to the other group? ".

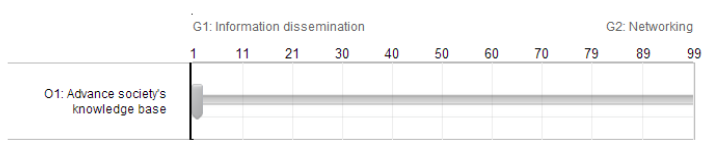
Click on the desired value on the scale.

Example: A = 20 ; B = 80



Comparison of G1 vs. G2

*



Comparison of G1 vs. G3

APPENDIX D-5: RESEACH INSTRUMENT 4.2 – QUANTIFYING THE RELATIVE IMPORTANCE OF THE UKTT MECHANISMS IN THE GROUPS

RESEARCH ON THE EVALUATION OF UNIVERSITY KNOWLEDGE AND TECHNOLOGY TRANSFER (UKTT) EFFECTIVENESS

Research Instrument 4.0: QUANTIFICATION OF THE RELATIVE IMPORTANCE OF UKTT MECHANISMS, INDICATORS AND DETERMINATION OF THE DESIRABILITY

In this instrument the experts will work on specific UKTT mechanisms and their indicators. Please click to select the group(s) of UKTT mechanisms you feel familiar with. Due to the limited number of experts available, selecting as many groups as you can is highly encouraged and appreciated.

- [ ] UKTT Mechanism Group 1: Information Dissemination (including informational materials, technology expositions, publications, conferences, industry seminars/workshops/presentations)
- [ ] UKTT Mechanism Group 2: Professional Networking (including professional organizations)
- [ ] UKTT Mechanism Group 3: Education and Training (including education & training for industry employees, joint supervision of students)
- [ ] UKTT Mechanism Group 4: Personnel Movement (including student internship, university graduate hiring by industry, faculty members with dual positions, temporary researcher exchange, faculty members moving to industry)
- [ ] UKTT Mechanism Group 5: Consulting (including advisory committees for industry, faculty consulting)
- [ ] UKTT Mechanism Group 6: Resource Sharing (including Materials Transfer Agreements, sharing of university facilities)
- [ ] UKTT Mechanism Group 7: Research (industry sponsored research, joint research, research alliance/consortium)
- [ ] UKTT Mechanism Group 8: Licensing (including licensing)
- [ ] UKTT Mechanism Group 9: New Business Creation (including start-ups)
- [ ] UKTT Mechanism Group 10: Supporting Infrastructure (including Technology Transfer Office, Incubator, Entrepreneurship center, Proof of Concept center, Technology Transfer intermediary partnerships, Research parks)

Informational materials versus Technology expositions

1 11 21 30 40 50 60 70 79 89 99

with respect to Information Dissemination

Informational materials versus journal papers

1 11 21 30 40 50 60 70 79 89 99

with respect to Information Dissemination

Informational materials versus Conference papers

1 11 21 30 40 50 60 70 79 89 99

with respect to Information Dissemination

Informational materials versus Seminars/Worshops

1 11 21 30 40 50 60 70 79 89 99

with respect to Information Dissemination

APPENDIX D-6: RESEACH INSTRUMENT 4.3 – QUANTIFYING THE RELATIVE IMPORTANCE OF THE INDICATORS OF THE UKTT MECHANISMS

RESEARCH ON THE EVALUATION OF UNIVERSITY KNOWLEDGE AND TECHNOLOGY TRANSFER (UKTT) EFFECTIVENESS

Research Instrument 4.0: QUANTIFICATION OF THE RELATIVE IMPORTANCE OF UKTT MECHANISMS, INDICATORS AND DETERMINATION OF THE DESIRABILITY VALUES

In this instrument the experts will work on specific UKTT mechanisms and their indicators. Please click to select the group(s) of UKTT mechanisms you feel familiar with. Due to the limited number of experts available, selecting as many groups as you can is highly encouraged and appreciated.

- ☐ UKTT Mechanism Group 1: Information Dissemination (including informational materials, technology expositions, publications, conferences, industry seminars/workshops/presentations)
- ☐ UKTT Mechanism Group 2: Professional Networking (including professional organizations)
- ☐ UKTT Mechanism Group 3: Education and Training (including education & training for industry employees, joint supervision of students)
- ☐ UKTT Mechanism Group 4: Personnel Movement (including student internship, university graduate hiring by industry, faculty members with dual positions, temporary researcher exchange, faculty members moving to industry)
- ☐ UKTT Mechanism Group 5: Consulting (including advisory committees for industry, faculty consulting)
- ☐ UKTT Mechanism Group 6: Resource Sharing (including Materials Transfer Agreements, sharing of university facilities)
- ☐ UKTT Mechanism Group 7: Research (industry sponsored research, joint research, research alliance/consortium)
- ☐ UKTT Mechanism Group 8: Licensing (including licensing)
- ☐ UKTT Mechanism Group 9: New Business Creation (including start-ups)
- ☐ UKTT Mechanism Group 10: Supporting Infrastructure (including Technology Transfer Office, Incubator, Entrepreneurship center, Proof of Concept center, Technology Transfer intermediary partnerships, Research parks)

*

Mechanism: TT informational materials

Question: How good is the online materials relative to the printed materials as an indicator of the informational material mechanism?

Online materials					versus					Printed materials
1	11	21	30	40	50	60	70	79	89	99

*

Mechanism: Journal papers

Question: How good is the number of journal papers relative to the number of journal paper citations as an indicator of the journal publication mechanism?

Number of journal papers					versus					Number of citations to the journal papers
1	11	21	30	40	50	60	70	79	89	99

*

Mechanism: Conference papers

Question: How good is the number of conference papers relative to the number of conference paper citations as an indicator of the conference mechanism?

Number of conference papers					versus					Number of citations to the conference papers
1	11	21	30	40	50	60	70	79	89	99

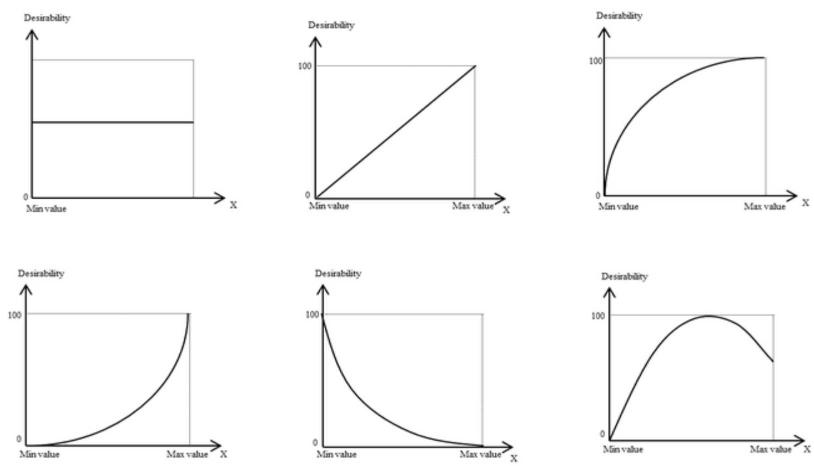
APPENDIX D-7: RESEACH INSTRUMENT 4.4 – DETERMINING THE DESIRABLE LUES OF THE METRICS

GROUP 1 - PART 3 : Providing desirability values for the metrics

Please READ the following instruction carefully:

In this research the indicators of the mechanisms are measured by metrics. In this section, you will help determine the desirability curves of the metrics. Desirability curve of a metric is a graphical representation of the desired values corresponding to the actual measurements of the metric. Desirability values reflect the "usefulness" of the indicators to the beneficiaries or users. For example, how desirable is having 8 new startups versus having 10 new startups in a year?. In practice the maximum value of a metric is not always the most desirable goal for a university. In this research, the use of desirability values enables the achievement of an effectiveness index of UKTT for a university.

Some representative examples of desirability curves are:

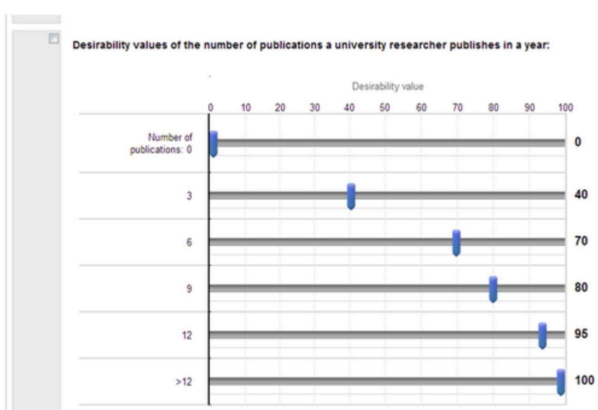


The desirability values are expressed on a 100 point scale with 100 being the most desirable value. Experts will help determine the desirability curve of a metric by providing a desirable value corresponding to a value of the metric. In other words, the question here is "how desirable is this value on a 100 point scale ?".

Due to the default question type of the survey software, in the following questions we will develop desirability curves that have different orientation than the examples above. For instance if you judge the desirability values for the average number of journal papers published by a university researcher in a given year as follows:

No. of papers	0	3	6	9	12	>12
Desirability value (points)	*0*	*40*	*70*	*80*	*95*	*100*

You would indicate in the instrument as follows:



Some indicators and metrics presented in this instrument may be debatable, but please use your intuition to interpret it and give estimates to the values. You can give your comments at the bottom of the page.

APPENDIX E : DESCRIPTIONS OF THE UKTT MECHANISMS

Group 1: Information dissemination. (G_1).

These mechanisms aim to provide information about new science and technologies (S&T) by the university to the public including industry.

- ✓ Informational Materials. (T1.1).

  This is the basic tech transfer mechanism, aiming to make the technology related information available to the public and raise the awareness of the public about a university's technological resources. This may include various informational forms such as websites (with technology searchable databases), brochures, pamphlets, flyers, newsletters, mailing lists, etc.
- ✓ Technology expositions. (T1.2).

  Technology expositions or fairs or shows are events where universities display and introduce new technologies or products to the public, particularly industry, with the intent to find potential users of the technologies.
- ✓ Journal publications. (T1.3).

  University researchers often choose to publish their research results in academic journals for academic accomplishment. Research results can also be conveyed in books, professional journals, institutional reports, news articles, etc. These are important channels to get the research results from the university out to the society. For the scope of this research we only look at the journal publications.
- ✓ Conferences. (T1.4).

  Conference presentations concerning results of research or discussions of work in progress are considered means of technology transfer. Conference presentations are often published in conference proceedings and distributed to conference attendees.
- ✓ Seminars and workshops. (T1.5).

  Seminar and workshops are classroom-like meetings among groups of people to work on specified topics through one or a series of sessions. The purpose of seminars and workshops is to update the participants with new information and knowledge in S&T. Participants can include university students and industry representatives.

Group 2: Professional networking. (G_2).

Social networking is the establishment of an individual's contacts with others belonging to the same interest group. The purpose of social networking is to expand relationships with more people and thus create more contact points which may be beneficial to the network member's work or life.

- ✓ Professional organization membership. (T2.1).

  A professional organization, also called a professional body, professional association, or professional society, is usually a non-profit organization seeking to further a particular profession, the interests of individuals engaged in that profession, and the public interest. Examples include the American Chemical Society, or the Association of Information Technology Professionals, and so on. Both university researchers and industry researchers can be members of the same professional bodies, so they have great chances to interact with each other through different channels such as conferences, meetings, or publications.

Group 3: Education and Training. (G_3).

This is a traditional channel of disseminating new knowledge and technology from faculty members to recipients. In the context of this study we focus on education and training offered by university researchers to industry.

- ✓ Education and Training programs for industry employees. (T3.1).

  Firms can send their staff to universities for degree programs or continuing education courses which are typically longer terms than short training classes. These education programs include CEU certificates, bachelor, master, or even PhD degrees. Through this education the industry staff's knowledge and technical expertise are updated in the required field.
- ✓ Joint supervision of students. (T3.2).

  University researchers and industry's senior researchers can co-supervise students in their research projects, if the academic institutions allow such a mechanism. These students, especially PhD students, act as intermediaries in exchanging new knowledge and technologies between the universities and firms.

Group 4: Personnel movement. (G_4).
Personnel movement refers to the flow of technical personnel between universities and firms.

- ✓ Student interns at firms. (T4.1).
  University or college students are usually sent to firms to learn hands on experience in the field for a short period of time during their education programs. In many circumstances the interns also bring new knowledge acquired at school to apply to the job where they intern. Student internship is usually short term and a part of the student's training curriculum.
- ✓ University graduate hiring by industry. (T4.2).
  Graduates from technical schools are hired by industry as new employees. These graduates bring with them new knowledge and technologies to the firms. This mode of technology transfer is particularly important to firms which do not have substantial R&D capabilities.
- ✓ Faculty members holding positions in both academic and industry. (T4.3).
  Many faculty members, particularly part time or adjunct professors, have positions in a university and a firm, or a university researcher spins off a new business from his invention and works on the new business without leaving his academic position.
- ✓ Temporary researcher exchange between the University and Industry. (T4.4).
  Exchange programs provide for a transfer of personnel either to the university from firms or from the university to firms. These arrangements are generally for the purpose of exchanging expertise and information. This mode or interaction can enhance the knowledge, expertise, and research of both parties and are excellent first steps toward long-term research alliances between university and industry. Generally, no proprietary data are exchanged, the cost is born by the organization sending the personnel, and the programs are short-term (usually one year).
- ✓ Faculty members moving to industry positions. (T4.5).
  In many circumstances the faculty members leave the academic positions to move to industry, or after they start up new businesses from their inventions. Upon joining the industry these people take with them the explicit and tacit knowledge that they have acquired in their academic life to apply in the commercial world. However this may cause a personnel problem at the university.

Group 5: Consulting. (G_5)
This group of mechanisms involves services that university researchers may provide to industry.

- ✓ Advisory committees. (T5.1).
  A firm may invite prominent university researchers to join its technological advisory committee or board. The committee meets on a periodical basis when the university researchers can advise the firm on technological issues such as technology planning, technology forecasting as well as emerging technologies.
- ✓ Consulting to industry by university researchers. (T5.2)
  Consulting services by university researchers to a company are provided by means of a contract. A firm may render consulting service from a university researcher on technical problems that the researcher has expertise on. These contracts are generally for a specific period of time and involve a well-defined scope of work.

Group 6: Resource sharing. (G_6)
These are agreements between the universities and firms to share the universities' resources with firms. These agreements help the firms, particularly small sized businesses, gain access to scarce resources available at the universities that are in need by the firms.

- ✓ Material Transfer Agreements (MTAs). (T6.1)
  A Material Transfer Agreement is a contract that governs the transfer of tangible research materials between two organizations, when the recipient intends to use it for his or her own research purposes. The MTA defines the rights of the provider and the recipient with respect to the materials and any derivatives developed by the university. Biological materials, such as reagents,

cell lines, plasmids, and vectors, are the most frequently transferred materials, but MTAs may also be used for other types of materials, such as chemical compounds and even some types of software, designs, prototypes, etc.

- ✓ Sharing of university facilities with industry. (T6.2)

  Facilities designated by the universities as "user facilities" contain unique, complex, experimental scientific equipment and expertise that are not readily available in the commercial sector. The university allows the use of shared facilities by the technical community, other universities, or industry to conduct specified research. Commonly shared facilities by a university with industry include research laboratories, equipment, buildings, centers, etc. Through sharing these facilities firms have access to specialty equipment owned by the university and learn from the university researchers.

Group 7: Research projects and programs. (G_7)

- ✓ Industry sponsored research. (T7.1)

  Research conducted by university researchers and sponsored, in full or in part, by industry partner(s). Industry sponsored research utilizes university expertise to solve a particular technical problem of the businesses. This is a popular TT mechanism used by the universities and provides a significant source of funding for the university research.
- ✓ University-Industry joint research. (T7.2)

  Also called collaborative or cooperative research. Both university and firm contribute resources to the project including personnel, facilities, funding to conduct research of mutual interest.
- ✓ Research alliance/Research center/ Research consortium . (T7.3)

  These are large-scale long-term research initiatives involving multiple universit(ies) and compani(es). The common purpose of these initiatives is to conduct basic research and develop new technologies that are strategic to the group of firms or an industry.

Group 8: Transfer of Intellectual Property Right (IPR). (G_8)

- ✓ Patent licensing. (T8.1)

  A license is a contract between a licensor (e.g., the holder or owner of a patent) and a licensee (e.g., an industry partner) that ensures the licensee that the licensor will not sue the licensee for patent infringement . Licensing is the most popular technology transfer mechanisms used by universities. A license can be exclusive or non-exclusive.

Group 9: New business creation. (G_9)

This group refers to mechanisms that require organizational setup. The most common means is to create a new business called start-up or spin-off taken with a technology developed by researchers at the university. Many universities, with a notable example of University of Utah, place strong emphasis on start-ups from in-house technologies and thus create various institutional mechanisms to support the process. For instance, entrepreneurship centers, venture funds, incubators, etc. The aim of these efforts is to foster the entrepreneurial culture and accelerate the commercialization of in house technologies at the university.

- ✓ Start-ups / Spin-offs. (T9.1)

  This mechanism refers to means used to generate new businesses using available technologies at the universities. Typically it involves a business incubator which hosts a number of new startups and provide them with necessary inputs as well as managerial expertise until they are mature enough to enter the marketplace on their own. Business incubators are also called under various names at different universities such as business accelerators, commercialization centers, etc. The output of these centers are new businesses growing out of the university's technologies. However a startup can spin off without going through the support centers at the university, except for clearing the IP with the university. In these cases the researcher typically takes his research result to the market by setting his own business and work with the industry' support.

Group 10: Supporting infrastructure. (G_{10})

This group refers to mechanisms that require institutional setup, some at very large scale. Some units can be hosted within the university or the university is one of multiple partners of the large scale joint ventures.

The general purpose of these institutional arrangements is to provide legal and/or physical infrastructure to facilitate research and technology transfer at the university.

- ✓ University Technology Transfer Office or Intellectual Property Office. (T10.1)

  The Technology Transfer Office (TTO) is a creation of the Bayh-Dole Act in 1980. Most research universities in the US now host a TTO, or one under a different name. The main function of a TTO is to manage the university's intellectual property pool by identifying, protecting, and transferring inventions by researchers to industry, mostly in the form of patents. Functions of TTO may include marketing of university technologies to industry and being liaison center between the university and industry. Many TTOs maintain technology databases that assist the search for technologies by companies. The TTO is also called Technology Licensing Office at some universities such as Stanford University and MIT.

- ✓ Technology Commercialization Support Facilities. (T9.2)

  Research at universities can be basic or applied by nature. Therefore in several circumstances the research results are not ready for commercialization. Many research universities have set up facilities to help bringing the basic research through many developmental phases until it is marketable. These support facilities include proof of concept centers, seed funds, venture funds, and the like. Creating new businesses also require managerial expertise, thus many universities also set up education centers to educate the staff/students on entrepreneurship. The common characteristic of these support facilities is to assist the intermediary phases of the new business creation process.

- ✓ Start-up Support Facilities. (T9.3)

  Universities can partner up with an independent technology transfer intermediary or brokers to facilitate the transfer process to the intended recipients of technologies

- ✓ Science/Technology/Research parks. (T10.4)

A science park is an area with a collection of buildings dedicated to scientific research on a business footing. There are many approximate synonyms for science park, including research park, technology park, technopolis and biomedical park. Often, science parks are associated with or operated by institutions of higher education (colleges and universities). Besides building area, these parks offer a number of shared resources, such as uninterruptible power supply, telecommunications hubs, reception and security, management offices, restaurants, bank offices, convention center, parking, internal transportation, entertainment and sports facilities, etc. In this way, the park offers considerable advantages to hosted companies, by reducing overhead costs with these facilities. Examples include the University of Arizona Science and Technology Park, Research Triangle Park in North Carolina.

APPENDIX F: DESCRIPTION OF INDICATORS AND METRICS OF UKTT MECHANISMS

TT Mechanism (T)	Description	Indicator (I)	Metric (E)	Desirability range
UKTT MECHANISM GROUP 1:INFORMATION DISSEMINATION				
T1.1. Informational materials	This is the basic tech transfer mechanism, aiming to make the technology related information available to the public and raise the awareness of the public about a university's technological resources. In this research technological information materials are categorized into two groups: online materials such as technology websites; and printed materials such as brochures, flyers, newsletters, posters, etc.	• Online materials, ($I_{1.1.1}$).	- Number of online material forms. ($E_{1.1.1}$), including: website, e-newsletter,social network sites (Facebook, Twitter, Linkedin,etc)	0 1 3 4 5 >5
		• Printed materials, ($I_{1.1.2}$) distributed to public.	- Types of printed materials distributed to public. ($E_{1.1.2}$), including: brochures, newsletters,flyers,posters,banners, etc.	0 1 3 5 7 >7
T1.2. Technology expositions	Technology expositions or fairs or shows are events where universities display and introduce new technologies or products to the public, particularly industry, with the intent to find potential users of the technologies	• Number of technology expositions in which the the university participates, ($I_{1.2.1}$).	- Number of technology expositions in which the university participates in a given year, ($E_{1.2.1}$).	0 1 3 5 7 >7
T1.3. Publications	University researchers often choose to publish their research results in academic journals for academic accomplishment. It is an important channel to get the new findings from research at the university out to the interested audiences. For the scope of this research we only consider journal publications.	• Number of publications (journal papers), ($I_{1.3.1}$).	- Average number of publications (journal papers) per researcher in a given year, ($E_{1.3.1}$).	0 3 6 9 12 >12
		• Number of citations to the academic papers, ($I_{1.3.2}$).	- Average number of citations of academic papers per researcher in a given year, ($E_{1.3.2}$).	0 $0<n \leq 10$ $10<n \leq 20$ $20<n \leq 30$ $30<n \leq 40$ $40<n \leq 50$ >50
T1.4. Conferences	Technical conference presentations to an audience and conference proceedings are other means to disseminate information about new knowledge and technologies to the public. Conferences enable the interaction between the researchers and the audience.	• Number of technical conference presentations, ($I_{1.4.1}$).	- Average number of technical conference presentations per researcher in a given year, (E1.4.1).	0 3 6 9 12 >12

		• Number of citations to conference papers ($I_{1.4.2}$).	- Average number of citations to conference papers per researcher in a given year ($E_{1.4.2}$).	0; 0<n ≤10; 10<n ≤20; 20<n ≤30; 30<n ≤40; 40<n ≤50; >50
T1.5. Industry seminars, workshops, presentations	Industry seminars, workshops, presentations are meetings of university researchers and industry people to discuss or train on specified topics through one or a series of sessions. The purpose of seminars, workshops, industry meetings is to update the industry participants with new information and knowledge in science and technology.	• Number of seminars, workshops or presentations provided by researchers in companies or industry meetings, ($I_{1.5.1}$).	- Number of seminars, workshops or presentations in in companies or industry meetings provided per researcher in a given year, ($E_{1.5.1}$).	0; 0<n ≤3; 3<n ≤6; 6<n ≤9; 9<n ≤12; >12
		• Number of attendants of the seminars, workshops, presentations made by university researchers ($I_{1.5.2}$).	- Average number of attendants in an industry presentation made by university researchers in a given year, ($E_{1.5.2}$).	0; 0<n ≤20; 20<n ≤40; 40<n ≤60; 60<n ≤80; 80<n ≤100; >100
UKTT MECHANISM GROUP 2: PROFESSIONAL NETWORKING				
T2.1. Professional organizations	Most university researchers are members of professional organizations in their disciplines. Professional organizations are usually non-profit organizations seeking to further a particular profession, the interests of individuals engaged in that profession, and the public interest. Through professional networks university researchers and industry people exchange information and initiate technology transfer.	• Number of university researchers having memberships in professional organizations related to their field, ($I_{2.1.1}$).	- Percentage of university researchers with memberships in professional organizations related to their field in a given year, %, ($E_{2.1.1}$).	0; 0<n ≤20; 20<n ≤40; 40<n ≤60; 60<n ≤80; 80<n ≤100; >100
		• Number of professional organizations of which a university researcher has memberships, ($I_{2.1.2}$).	- Average number of professional organizations in which a researcher has memberships in a given year, ($E_{2.1.2}$).	0; 0<n ≤2; 2<n ≤4; 4<n ≤6; 6<n ≤8; >8
UKTT MECHANISM GROUP 3:EDUCATION AND TRAINING FOR INDUSTRY				
T3.1. Industry employee education &	Industry employees often receive training from universities through short courses, continuing education, or degree programs. These education programs include certificate courses, bachelor, master, or even PhD degrees. Through this education	• Number of students currently working in industry ($I_{3.1.1}$).	- Percentage of students employed by industry in a given year~~,~~ (%), ($E_{3.1.1}$).	0; 0<n ≤20; 20<n ≤40; 40<n ≤60; 60<n ≤80; 80<n ≤100; >100

training	knowledge and technologies are transferred from faculty to industry employees.	• Number of faculty members conducting short training courses for industry ($I_{3.1.2}$).	- Percentage of faculty members conducting short training courses for industry in a given year, ($E_{3.1.2}$).	0 · 0<n ≤20 · 20<n ≤40 · 40<n ≤60 · 60<n ≤80 · 80<n ≤100 · >100
T3.2. Joint supervision of students	University researchers and industry's senior researchers can co-supervise students in their research projects, if the academic institutions allow such a mechanism. These students, especially PhD students, act as intermediaries in exchanging new knowledge and technologies between the universities and firms	• Number of students jointly supervised by faculty members and industry advisors, ($I_{3.2.1}$).	- Percentage of students jointly supervised by faculty members and industry advisors in a given year, %, ($E_{3.2.1}$).	0 · 0<n ≤5 · 5<n ≤10 · 10<n ≤15 · 15<n ≤20 · 20<n ≤25 · >25
UKTT MECHANISM GROUP 4: PERSONNEL MOVEMENT				
T4.1. Student internship	University or college students are usually sent to firms to learn hands on experience in the field for a short period of time during their education programs. In many circumstances the interns also bring new knowledge acquired at school to apply to the job where they intern. Student internship is usually short term and a part of the student's training curriculum	• Number of students with internships in industry, ($I_{4.1.1}$).	- Percentage of students with internships in industry in a given year, %, ($E_{4.1.1}$).	0 · 0<n ≤5 · 5<n ≤10 · 10<n ≤15 · 15<n ≤20 · 20<n ≤25 · >25
T4.2. University graduate hiring by industry	Science and technical (S&T) graduates from universities are hired by technology based industries as new employees. These graduates bring with them new knowledge and technologies acquired at their universities to the firms.	• Number of S&T graduates from university hired by technology based industries, ($I_{4.2.1}$).	- Percentage of university graduates hired by technology based industries in a given year, %, ($E_{4.2.1}$).	0 · 20 · 40 · 60 · 80 · 100
4.3. Faculty members with dual positions	Many faculty members, particularly part time or adjunct professors, have positions in a university and a firm, or a university researcher spins off a new business from his invention and works on the new business without leaving his academic position.	• Number of faculty members holding positions both at university and a firm, ($I_{4.3.1}$).	- Percentage of faculty members holding positions both at the university and a technological firm in a given year, %, ($E_{4.3.1}$).	0 · 5 · 10 · 15 · 20 · 25 · >25

T4.4. Temporary researcher exchange	Exchange programs place faculty members temporarily at a firm. These arrangements are generally for the purpose of exchanging expertise and information, or investigate industry problems in depth. This mode or interaction can enhance the knowledge, expertise, and research of both parties and are excellent first steps toward long-term research alliances between university and industry.	• Number of university researchers exchanged temporarily to industry, ($I_{4.4.1}$).	- Percentage of university researchers exchanged temporarily to industry in a given year, %, ($E_{4.4.1}$).	0 5 10 15 20 25 >25
T4.5. Faculty members moving to industry	In many circumstances faculty members leave the academic positions to move to industry, or after they start up new businesses from their inventions. Upon joining the industry these people take with them the explicit and tacit knowledge that they have acquired in their academic life to apply in the commercial world. However this may cause a personnel problem at the university.	• Number of university researchers moving permanently to industry, ($I_{4.5.1}$).	- Percentage of university researchers moving permanently to industry in a given year, %, ($E_{4.5.1}$).	0 5 10 15 20 25 >25
UKTT MECHANISM GROUP 5: CONSULTING				
T5.1. Advisory committees	A firm may invite prominent university researchers to join its technological advisory committee. The committee meets on a periodical basis when the university researchers advise the firm on technological issues such as technology planning, technology forecasting as well as emerging technologies	• Number of university researchers serving in industry advisory committees, ($I_{5.1.1}$).	- Percentage of university researchers serving in an advisory committees in industry in a given year, %, ($E_{5.1.1}$).	0 5 10 15 20 25 >25
T5.2. Consulting	Consulting services by university researchers to companies is a form of knowledge and technology transfer. Consulting can transfer tacit or sticky knowledge from university researchers to industry employees. In this research, all reported and unreported consulting agreements between faculty members and companies are considered to reflect the impact of knowledge and technology transfer.	• Number of university researchers doing consulting to industry, ($I_{5.2.1}$).	- Percentage of university researchers providing consulting to industry in a given year, ($E_{5.2.1}$).	0 10 20 30 40 50 >50
		• Number of consulting agreements with industry performed by university researchers, ($I_{5.2.2}$).	- Average number of consulting agreements with industry performed by a university researcher in a given year, ($E_{5.2.2}$).	0 1 2 3 4 5 >5
UKTT MECHANISM GROUP 6: RESOURCE SHARING				

T6.1. Materials Transfer Agreements (MTAs)	A Material Transfer Agreement is a contract to transfer tangible research materials between the university and the firm, when the recipient intends to use it for its own research purposes. Biological materials, such as reagents, cell lines, plasmids, and vectors, are the most frequently transferred materials, but MTAs may also be used for other types of materials, such as chemical compounds and even some types of software, designs, prototypes, etc. In this research only outbound (from university to industry) MTAs are considered.	• Number of outbound MTAs undertaken at the university, ($I_{6.1.1}$).	- Number of outbound MTAs undertaken at the university in a given year, ($E_{6.1.1}$).	0 0<n ≤50 50<n ≤100 100<n ≤150 150<n ≤200 >200
T6.2. Sharing of university facilities	Facilities designated by the universities as “user facilities” contain unique, complex, experimental scientific equipment and expertise that are not readily available in the commercial sector. The university allows the use of shared facilities by the technical community, other universities, or industry to conduct specified research. Commonly shared facilities by a university with industry include research laboratories, equipment, buildings, centers, etc. Through sharing these facilities firms have access to specialty equipment owned by the university and learn from the university researchers	• Number of companies use university’s research facilities, ($I_{6.2.1}$).	- Number of companies using university owned research facilities in a given year, ($E_{6.2.1}$).	0 0<n ≤10 10<n ≤20 20<n ≤30 30<n ≤40 >40
UKTT MECHANISM GROUP 7: RESEARCH				
T7.1. Industry sponsored research	Research conducted by university researchers and sponsored, in full or in part, by industry partner(s). Industry sponsored research utilizes university expertise to solve a particular technical problem of the businesses. This is a popular UKTT mechanism and it provides a significant source of funding for the university research	• Number of research projects sponsored by industry, ($I_{7.1.1}$).	- Number of research projects sponsored by industry in a given year, ($E_{7.1.1}$).	0 50 100 150 200 250 >250
		• Expenditures of industry sponsored research, ($I_{7.1.2}$).	- Average size of industry-sponsored research in a given year, $. ($E_{7.1.2}$).	0K 50K 100K 150K 200K 250K ≥250K
T7.2. Joint research	Also called collaborative or cooperative research. Both university and firm contribute resources to the project including personnel, facilities, funding to conduct research of mutual interest	• Number of joint research between university and industry, ($I_{7.2.1}$).	- Number of joint research projects between university and industry in a given year, ($E_{7.2.1}$).	0-20 21-40 41-60 61-80 81-100 >100

T7.3. Research alliance/ research consortium	These are large-scale long-term research initiatives involving multiple universit(ies) and compani(es). The common purpose of these initiatives is to conduct research on development, implementation, or evaluation of current and emerging technologies that are strategic to the group of firms or an industry. Examples include NSF's Industry/UniversityCollaborative Research Centers (IUCRC) and similar consortia.	• Number of research alliances/consortia established between university and industry with or without government support, ($I_{7.3.1}$).	- Number of existing research alliances /consortia established between university and industry in a given year, ($E_{7.3.1}$).	0 2 3 4 5 6 >7
		• Number of university researchers participating in these initiatives, ($I_{7.3.3}$).	- Percentage of university researchers participating in those initiatives in a given year, %, ($E_{7.3.3}$).	0 10 20 30 40 50 >50
		• Number of companies involved in these research initiatives, ($I_{7.3.4}$).	- Average number of companies involved in a research initiative in a given year, ($E_{7.3.4}$).	0 0<n ≤5 5<n ≤10 10<n ≤15 15<n ≤20 >20
UKTT MECHANISM GROUP 8: LICENSING				
T8.1. Licensing	A license is a contract between a licensor (e.g., the holder or owner of a patent) and a licensee (e.g., an industry partner) that ensures the licensee that the licensor will not sue the licensee for patent infringement . Licensing is the most popular technology transfer mechanisms used by universities. A license can be exclusive or non-exclusive	• Number of new licenses executed, ($I_{8.1.1}$).	- Number of new licenses executed in a given year, ($E_{8.1.1}$).	0 40 60 80 100 ≥100
		• Income (royalty) of the executed licenses per researcher, ($I_{8.1.2}$).	- Average income (royalty) of an executed license, in thousands of dollars in a given year, ($E_{8.1.2}$).	0-50K 51-100K 101-150K 151-200K 201K-250K 251-300K 301-350K >350K
		• Number of new technologies transferred to industry, ($I_{8.1.3}$).	- Number of new technologies transferred to industry in a given year, ($E_{8.1.3}$).	0 40 60 80 100 ≥100
UKTT MECHANISM GROUP 9: NEW BUSINESS CREATION				

T9.1. Start-up/Spin-off	This mechanism refers to means used to generate new businesses using available technologies at the universities. Typically it involves a business incubator which hosts a number of new startups and provide them with necessary inputs as well as managerial expertise until they are mature enough to enter the marketplace on their own. However a startup can spin off without going through the support centers at the university, except for clearing the IP with the university. In these cases the researcher typically takes his research result to the market by setting up his own business using personal support network or with the support of non-university start up centers.	• Number of new startup companies formed that were dependent upon the licensing of the university's technology for initiation , ($I_{9.1.1}$).	- Number of new startup companies formed in a given year, ($E_{9.1.1}$).	5 15 25 30 0 10 20 >30
		• Number of researchers participating in startups, (I9.1.2).	- Percentage of researchers participating in startups in a given year, %, (E9.1.2).	0 5 10 15 20 25 >25
UKTT MECHANISM GROUP 10: SUPPORTING INFRASTRUCTURE				
T10.1. TTO	The Technology Transfer Office (TTO) is a creation of the Bayh-Dole Act in 1980. Most research universities in the US now host a TTO, or one under a different name. The main function of a TTO is to manage the university's intellectual property pool by identifying, protecting, and transferring inventions by researchers to industry, mostly in the form of patents. Functions of TTO may include marketing of university technologies to industry and being liaison center between the university and industry. Many TTOs maintain technology databases that assist the search for technologies by companies. The TTO is also called Technology Licensing Office (ex: Stanford University, MIT), or Tech Commercialization Office (ex: University of Utah)	• Number of full time licensing employees (FTEs), ($I_{9.1.1}$).	- Number of licensing FTEs in TTO in a given year, ($E_{9.1.1}$).	0 0<n ≤5 5<n ≤10 10<n ≤15 15<n ≤20 25<n ≤30 30<n ≤35 >35

T10.2.Technology commercialization support facilities	Research results at universities can be ready for commercialization, or still basic by nature. Many universities have set up facilities and/or programs to help bring the basic research through developmental phases until it is marketable. These support facilities/programs include proof of concept centers, seed funds, venture funds, incubators, commercialization centers, entrepreneurship centers and the like. Creating new businesses also require managerial expertise, thus many universities have also set up entrepreneurship centers to educate the staff/students on entrepreneurship. The common characteristic of these support facilities is to assist and facilitate the different phases of the new business creation process.	• Combination of technology commercialization support centers, ($I_{10.2.1}$).	- Total number of tech commercialization support centers/programs existing at the university in a given year, such as: • incubator • commercialization center • tech development center • entrepreneurship center • proof of concept center • seed fund program/center • tech. maturation fund • entrepreneur-in-residence program • venture pitch competition ($E_{.10,2.1}$).	0 1 2 3 4 5 6 7 8 9 10 >10
		• Number of projects supported by technology commercialization support facilities, ($I_{10,2.2}$).	- Average number of existing projects supported by one of these facilities in a given year, ($E_{10.2.2}$).	0 10 20 30 40 50 >50
T.10.3. Tech transfer Intermediary partnership	Independent tech transfer organizations affiliated with a state or local government or private sector to assist companies utilizing university technologies and serve as a technology broker	• Number of independent TT intermediaries with whom the university has partnerships	- Number of existing TT intermediaries with whom the university has partnerships in a given year ($E_{10.3.1}$).	0 1 2 3 4 5 >5
T10.4. Research / Technology/ Science parks	A science park is an area with a collection of buildings dedicated to scientific research on a business footing. There are many approximate synonyms for science park, including research park, technology park, technopolis and biomedical park. Often, science parks are associated with or operated by institutions of higher education (colleges and universities). Besides building area, these parks offer a number of shared resources, such as uninterruptible power supply, telecommunications hubs, reception and security, management offices, restaurants, bank offices, convention center, parking, internal transportation, entertainment and sports facilities, etc. In this way, the	• Number of research/ technology/ science parks the university participates in, ($I_{10.4.1}$).	- Number of existing research /technology /science parks in which the university participates in a given year, ($E_{10.4.1}$).	0 1 2 3 4 5 >5
		• Number of companies participating in the research/ technology/ science parks, ($I_{10.4.2}$).	- Average number of existing companies in a research/technology/science park in which the university participates in a given year, ($E_{10.4.2}$).	0 20 40 60 80 100

	park offers considerable advantages to hosted companies, by reducing overhead costs with these facilities. Examples include the University of Arizona Science and Technology Park, Research Triangle Park in North Carolina	• Number of university researchers conducting research at the research/technology/science parks, ($I_{10.4.3}$)	- Percentage of university researchers doing research at the research/ technology/ science parks in a given year, %, ($E_{10.4.3}$)	0 10 20 30 40 50 >50

APPENDIX G : MODEL VERIFICATION BY EXPERTS

APPENDIX G-1: VERIFICATION OF THE UKTT OBJECTIVES

	Expert code	O1	O2	O3	O4	O5
1	UA1	Yes	Yes	Yes	Yes	Yes
2	UA2	No	Yes	Yes	Yes	Yes
3	UA3	Yes	Yes	Yes	Yes	No
4	AR13	Yes	Yes	Yes	Yes	Yes
5	TM9	Yes	Yes	Yes	Yes	Yes
6	TM8	Yes	Yes	Yes	Yes	Yes
7	TM6	Yes	Yes	Yes	Yes	Yes
	Agreement	**85%**	**100%**	**100%**	**100%**	**85%**

APPENDIX G-2: VERIFICATION OF THE UKTT MECHANISM GROUPS

APPENDIX G–2-1: VERIFICATION OF THE UKTT MECHANISM GROUPS WITH RESPECT TO UKTT OBJECTIVE 1

	Expert code	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
1	AR1	1	1	1	1	1	1	1	1	1	1
2	AR2	1	1	1	0	1	1	1	1	1	1
3	AR3	1	1	0	1	1	0	0	1	1	0
4	AR4	1	1	1	1		1	1	1	1	1
5	AR5	1	1	1	0	1	1	1	1	1	1
6	AR6	1	1	1	1	1	1	1	1	1	1
7	AR7	1	1	1	1	1	1	1	1	1	1
8	AR8	1	1	1	1	1	1	1	0	1	1
9	AR9	1	1	1	0	0	0	1	0	0	0
11	AR10	1	1	1	1	1	1	1	1	1	1
12	AR11	1	1	1	1	1	1	1	0	1	1
13	AR12	1	1	1	1	1	1	1	1	1	1
15	AR14	1	1	1	1	0	0	1	1	1	0
16	AR15	1	1	1	1	1	1	1	1	1	1
19	AR16	1	1	0	1	1	1	0	1	1	1
20	AR17	1	0	1	1	0	1	0	0	1	1
21	AR18	1	1	1	0	1	1	1	1	1	0
22	AR19	1	1	1	1	1	1	1	1	1	1
24	AR20	1	1	1	1	1	1	1	1	1	1
25	AR21	1	1	1	1	1	1	1	1	1	1
26	AR22	1	1	1	1	1	1	1	1	1	1
27	TM1	1	1	1	1	0	1	1	1	1	0
28	TM3	1	1	1	0	0	1	1	1	1	1
29	TM4	1	1	1	1	1	1	1	1	1	1
30	TM5	1	1	1	1	1	1	1	1	1	1
31	TM6	1	1	1	1	1	1	1	1	1	1
	Agreement:	**100%**	**96%**	**92%**	**81%**	**77%**	**88%**	**88%**	**85%**	**96%**	**81%**

1: agree
0: do not agree
G: Group of UKTT mechanisms

APPENDIX G–2-2: VERIFICATION OF THE UKTT MECHANISM GROUPS WITH RESPECT TO UKTT OBJECTIVE 2

	Expert code	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
1	AR1	1	1	1	1	1	1	1	1	1	1
2	AR2	1	1	1	1	1	1	1	1	1	1
3	AR3	1	1	1	1	1	1	1	1	1	1
4	AR4	1	1	1	1	1	1	1	1	1	1
5	AR5	1	1	0	1	1	1	1	1	1	0
6	AR6	1	1	1	1	1	1	1	1	1	1
7	AR7	1	1	1	1	1	1	1	1	1	1
8	AR8	1	1	1	1	1	1	1	1	1	1
9	AR9	1	1	0	1	0	1	1	0	1	0
10	AR10	1	1	1	1	1	1	1	1	1	1
11	AR11	1	1	1	1	0	1	1	1	1	1
12	AR12	1	1	1	1	1	0	1	1	1	1
13	AR14	0	0	1	1	0	0	0	1	1	0
14	AR15	1	1	1	1	1	1	1	1	1	1
15	AR16	1	1	1	1	1	1	1	1	1	1
16	AR17	1	1	1	1	1	1	1	1	1	1
17	AR18	1	1	1	1	1	1	1	1	1	1
18	AR19	1	1	1	1	1	1	1	1	1	1
19	AR20	1	1	1	1	1	1	1	1	1	1
20	AR21	1	1	1	1	1	1	1	1	1	1
21	AR22	1	1	1	1	1	1	1	1	1	1
22	TM1	1	1	1	1	0	1	1	1	1	1
23	TM3	1	1	1	0	0	1	1	1	1	1
24	TM4	1	1	1	1	1	1	1	1	1	1
25	TM5	1	1	1	1	1	1	1	1	1	1
26	TM6	1	1	1	1	0	1	1	1	1	1

	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
Agreement:	**96%**	**96%**	**92%**	**96%**	**77%**	**92%**	**96%**	**96%**	**100%**	**88%**

1: agree
0: do not agree
G: Group of UKTT mechanisms

APPENDIX G–2-3: VERIFICATION OF THE UKTT MECHANISM GROUPS WITH RESPECT TO UKTT OBJECTIVE 3

	Expert code	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
1	AR1	1	1	1	1	1	1	1	1	1	1
2	AR2	1	1	1	1	1	1	1	1	1	1
3	AR3	0	1	1	1	1	0	1	1	1	1
4	AR4	1	1	1	1	1	1	1	1	1	1
5	AR5	1	1	1	1	1	1	1	1	1	1
6	AR6	1	1	1	1	1	1	1	1	1	1
7	AR7	1	1	1	1	1	1	1	1	1	1
8	AR8	1	1	1	1	1	1	1	1	1	1
9	AR9	0	1	1	1	0	1	0	1	1	1
10	AR10	1	1	1	1	1	1	1	1	1	1
11	AR11	1	1	1	1	1	1	1	0	1	1
12	AR12	1	1	1	1	1	1	1	1	1	1
13	AR14	1	1	1	1	1	1	1	1	1	1
14	AR15	1	1	1	1	1	1	1	1	1	1
15	AR16	1	1	1	1	1	1	1	1	1	1
16	AR17	0	1	1	1	1	1	1	1	1	1
17	AR18	1	1	1	1	1	1	1	1	1	1
18	AR19	0	0	1	1	0	1	0	0	1	1
19	AR20	1	1	1	1	1	1	1	1	1	1
20	AR21	1	1	1	1	1	1	1	1	1	1
21	AR22	1	1	1	1	1	1	1	1	1	1
22	TM1	1	1	0	0	0	0	0	1	1	0
23	TM3	1	1	1	0	0	1	1	1	1	1
24	TM4	1	1	1	1	1	1	1	1	1	1
25	TM5	0	1	1	1	0	1	0	0	1	0
26	TM6	1	1	1	1	1	1	0	1	1	1
	Agreement:	**81%**	**96%**	**96%**	**92%**	**81%**	**92%**	**81%**	**88%**	**100%**	**92%**

1: agree
0: do not agree
G: Group of UKTT mechanism

APPENDIX G-2-4: VERIFICATION OF THE UKTT MECHANISM GROUPS WITH RESPECT TO UKTT OBJECTIVE 4

	Expert code	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
1	AR1	1	1	1	1	1	1	1	1	1	1
2	AR2	1	1	1	1	1	1	1	1	1	1
3	AR3	1	0	0	0	0	0	1	0	0	0
4	AR4	1	1	1	1	1	1	1	1	1	1
5	AR5	1	1	0	1	1	1	1	1	1	1
6	AR6	1	1	1	1	1	1	1	1	1	1
7	AR7	1	1	1	1	1	1	1	1	1	1
8	AR8	1	1	1	1	1	1	1	1	1	1
9	AR9	1	1	1	0	0	1	1	0	1	0
10	AR10	1	1	1	1	1	0	1	0	1	1
11	AR11	0	1	1	1	1	0	1	1	1	1
12	AR12	1	1	1	1	1	1	1	1	1	1
13	AR14	1	1	0	1	0	0	1	0	1	1
14	AR15	1	1	0	1	0	0	0	1	1	1
15	AR16	1	1	1	1	0	0	1	0	1	1
16	AR17	1	1	1	1	1	1	1	1	1	1
17	AR18	1	1	1	1	1	1	1	1	1	1
18	AR19	1	1	1	1	1	0	1	1	1	0
19	AR20	1	1	1	1	1	1	1	1	1	1
20	AR21	1	1	1	1	1	1	1	1	1	1
21	AR22	1	1	1	1	1	1	1	1	1	1
22	TM1	1	1	1	1	1	1	1	1	1	1
23	TM3	1	1	1	0	0	0	0	1	1	0
24	TM4	1	1	1	1	1	1	1	1	1	1
25	TM5	0	1	0	0	0	0	0	1	1	0
26	TM6	1	1	1	0	0	1	0	1	1	1
	Agreement:	**92%**	**96%**	**81%**	**81%**	**69%**	**65%**	**85%**	**81%**	**96%**	**81%**

1: agree
0: do not agree
G: Group of UKTT mechanisms

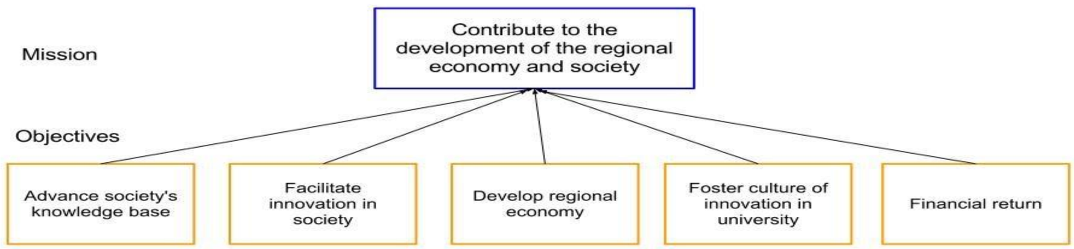
APPENDIX G–2-5: VERIFICATION OF THE UKTT MECHANISM GROUPS WITH RESPECT TO UKTT OBJECTIVE 5

	Name	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
1	AR1	1	1	1	1	1	1	1	1	1	1
2	AR2	1	1	1	1	1	1	1	1	1	1
3	AR3	0	1	0	0	1	0	0	1	1	0
4	AR4	1	1	1	1	1	1	1	1	1	1
5	AR5	0	1	1	1	1	1	0	1	0	1
6	AR6	0	0	1	0	1	1	1	1	1	0
7	AR7	1	1	1	1	1	1	1	1	1	1
8	AR8	0	0	1	0	0	0	0	1	1	1
9	AR9	1	1	0	1	0	1	0	1	1	1
10	AR10	1	1	0	0	1	0	1	1	1	1
11	AR11	0	1	1	0	1	1	0	1	1	0
12	AR12	1	1	0	0	1	0	1	1	1	0
13	AR14	0	0	0	0	0	0	1	1	1	0
14	AR15	1	0	0	1	1	0	0	1	1	1
15	AR16	1	1	1	1	1	1	0	1	1	1
16	AR17	0	0	1	0	1	1	1	1	1	1
17	AR18	0	1	1	1	0	1	1	1	1	0
18	AR19	0	0	1	0	1	1	1	1	1	1
19	AR20	1	1	1	1	1	1	1	1	1	1
20	AR21	1	1	1	1	1	1	1	1	1	1
21	AR22	1	1	1	0	1	1	1	1	1	1
22	TM1	1	1	0	1	0	0	0	1	1	0
23	TM3	1	1	1	0	0	1	1	1	1	1
24	TM4	1	1	1	1	1	1	1	1	1	1
25	TM5	0	0	0	0	0	0	0	0	0	0
26	TM6	1	1	1	0	0	0	0	1	1	0
	Agreement:	**62%**	**73%**	**69%**	**50%**	**69%**	**65%**	**62%**	**96%**	**92%**	**65%**

1: agree
0: do not agree
G: Group of UKTT mechanisms

APPENDIX H: PAIRWISE COMPARISON RESULTS

APPENDIX H-1: PAIRWISE COMPARISON OF THE UKTT OBJECTIVES WITH RESPECT TO THE MISSION

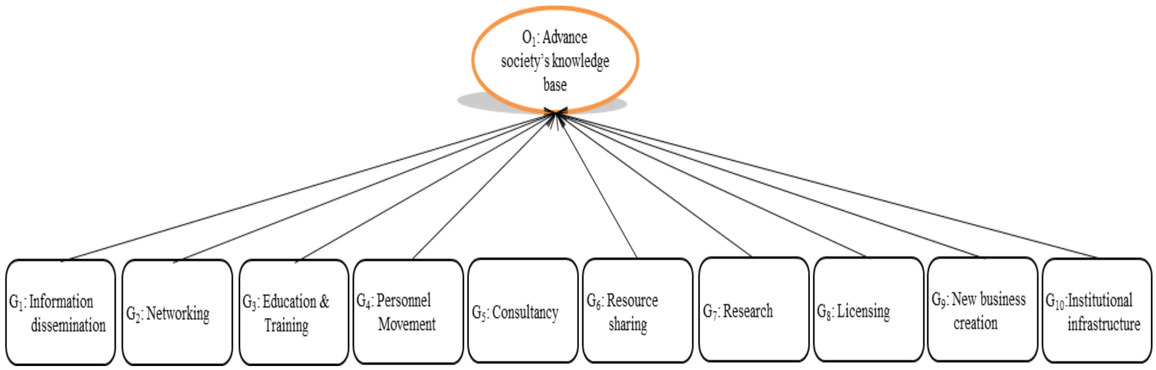


UKTT mission	O1: Advance society's knowledge base	O2: Facilitate innovation in society	O3: Develop regional economy	O4: Foster culture of innovation in university	O5: Financial return
UA1	0.07	0.07	0.03	0.09	0.74
UA2	0.2	0.21	0.15	0.15	0.29
UA3	0.12	0.19	0.25	0.37	0.07
Mean	**0.13**	**0.16**	**0.14**	**0.2**	**0.36**
Minimum	**0.07**	**0.07**	**0.03**	**0.09**	**0.06**
Maximum	**0.2**	**0.21**	**0.25**	**0.37**	**0.74**
Std. Deviation	**0.05**	**0.06**	**0.09**	**0.12**	**0.28**

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.11	4	.027	**.65**
Between Conditions:	0.00	2	0.000	
Residual:	0.33	8	0.041	
Total:	**0.44**	**14**		
Critical F-value with degrees of freedom 4 & 8 at 0.01 level:				**7.01**
Critical F-value with degrees of freedom 4 & 8 at 0.025 level:				**5.05**
Critical F-value with degrees of freedom 4 & 8 at 0.05 level:				**3.84**
Critical F-value with degrees of freedom 4 & 8 at 0.1 level:				**2.81**

APPENDIX H-2: PAIRWISE COMPARISON OF THE UKTT MECHANISM GROUPS.

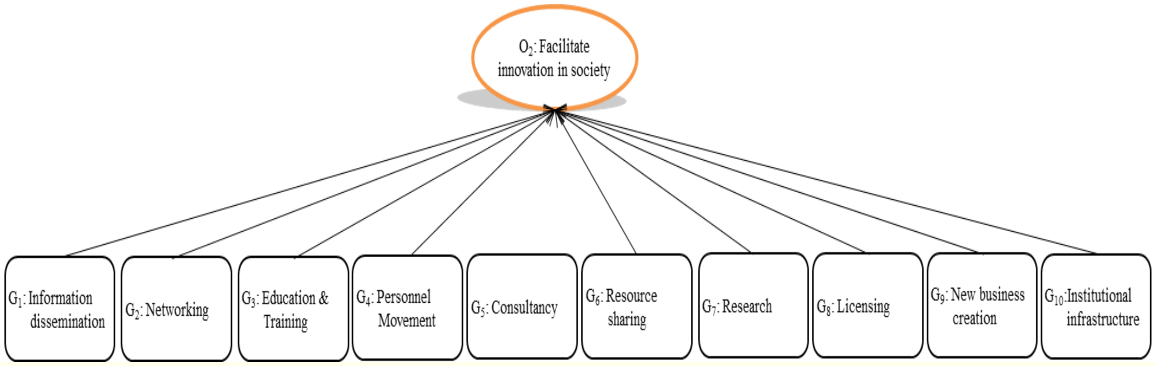
APPENDIX H-2-1: PAIRWISE COMPARISON OF THE UKTT MECHANISM GROUPS WITH RESPECT TO THE UKTT OBJECTIVE 1 “ADVANCE KNOWLEDGE BASE OF SOCIETY”



O1: Advance knowledge base of society	G1: Information dissemination	G2: Networking	G3: Education & Training	G4: Personnel movement	G6: Resource sharing	G7: Research	G8: Licensing	G9: New business creation	G10: Institutional infrastructure	Inconsistency
AR6	0.12	0.07	0.03	0.18	0.21	0.03	0.16	0.14	0.07	0.03
AR19	0.17	0.04	0.23	0.07	0.04	0.44	0.01	0.01	0	0.06
AR1	0.17	0.09	0.17	0.1	0.02	0.36	0.02	0.05	0.02	0.01
AR15	0.15	0.06	0.19	0.22	0.2	0.12	0.03	0.02	0.02	0.06
AR21	0.1	0.11	0.05	0.19	0.16	0.06	0.11	0.1	0.1	0.04
AR9	0.07	0.09	0.09	0.28	0.3	0.02	0.07	0.04	0.03	0.08
AR16	0.17	0.12	0.08	0.1	0.13	0.09	0.12	0.1	0.09	0.01
Mean	**0.14**	**0.08**	**0.12**	**0.16**	**0.15**	**0.16**	**0.07**	**0.07**	**0.05**	
Minimum	**0.07**	**0.04**	**0.03**	**0.07**	**0.02**	**0.02**	**0.01**	**0.01**	**0.02**	
Maximum	**0.17**	**0.12**	**0.23**	**0.28**	**0.3**	**0.44**	**0.16**	**0.14**	**0.1**	
Std. Deviation	**0.04**	**0.03**	**0.07**	**0.07**	**0.09**	**0.16**	**0.05**	**0.04**	**0.04**	
Disagreement										**0.07**

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.11	8	.014	**1.85**
Between Conditions:	0.00	6	0.000	
Residual:	0.36	48	0.007	
Total:	**0.47**	**62**		
Critical F-value with degrees of freedom 8 & 48 at 0.01 level:				**2.91**
Critical F-value with degrees of freedom 8 & 48 at 0.025 level:				**2.47**
Critical F-value with degrees of freedom 8 & 48 at 0.05 level:				**2.14**
Critical F-value with degrees of freedom 8 & 48 at 0.1 level:				**1.8**

APPENDIX H-2-2: PAIRWISE COMPARISON OF THE UKTT MECHANISM GROUPS WITH RESPECT TO THE UKTT OBJECTIVE 2 “FACILITATE INNOVATION IN SOCIETY”

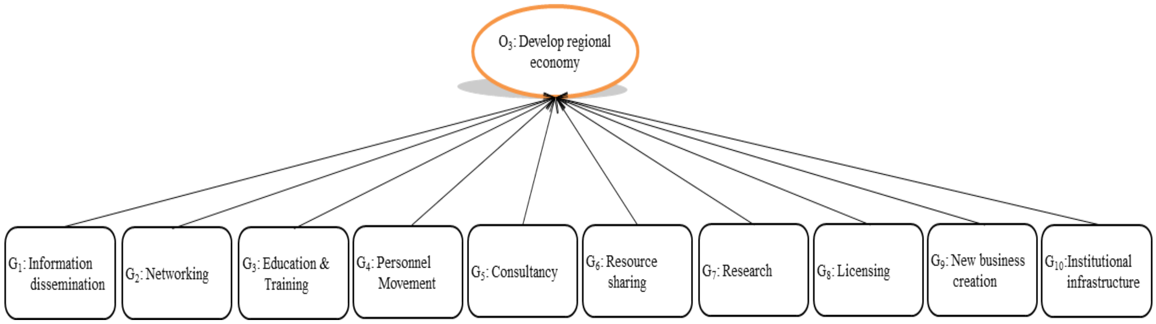


Networking	Number of researchers with professional memberships	Number of memberships per researcher	Inconsistency
AR10	0.5	0.5	0
AR1	0.62	0.38	0
AR4	0.7	0.3	0
AR21	0.5	0.5	0
AR18	0.5	0.5	0
AR16	0.6	0.4	0
TM10	0.6	0.4	0
Mean	**0.57**	**0.43**	
Minimum	**0.5**	**0.3**	
Maximum	**0.7**	**0.5**	
Std. Deviation	**0.07**	**0.07**	
Disagreement			**0.07**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.08	1	.077	**6.48**
Between Conditions:	0.00	6	0.000	
Residual:	0.07	6	0.012	
Total:	**0.15**	**13**		
Critical F-value with degrees of freedom 1 & 6 at 0.01 level:				**13.75**
Critical F-value with degrees of freedom 1 & 6 at 0.025 level:				**8.81**
Critical F-value with degrees of freedom 1 & 6 at 0.05 level:				**5.99**
Critical F-value with degrees of freedom 1 & 6 at 0.1 level:				**3.78**

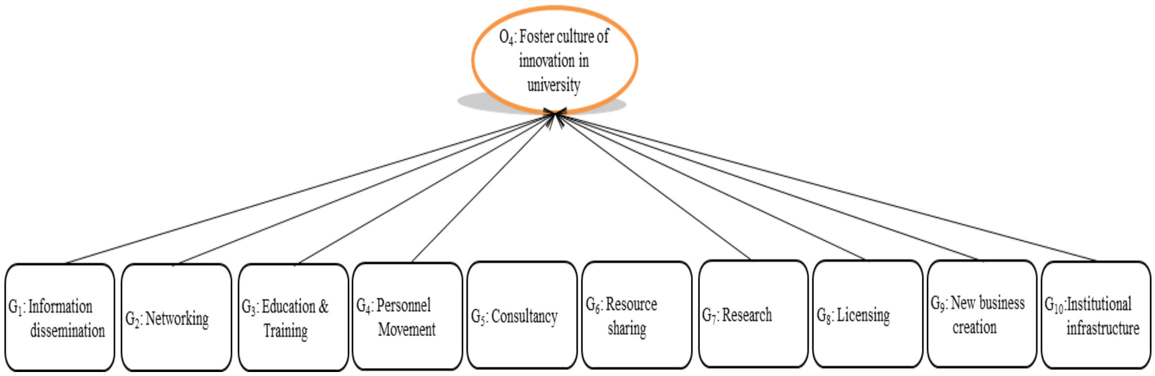
APPENDIX H-2-3: PAIRWISE COMPARISON OF THE UKTT MECHANISM GROUPS WITH RESPECT TO THE UKTT OBJECTIVE 3 “DEVELOP REGIONAL ECONOMY”



Education and Training	E&T programs for industry	Joint supervision of students	Inconsistency
AR10	0.6	0.4	0
AR19	0.7	0.3	0
TM7	0.5	0.5	0
AR1	0.66	0.34	0
AR4	0.5	0.5	0
AR22	0.5	0.5	0
AR21	0.8	0.2	0
AR18	0.6	0.4	0
AR5	0.46	0.54	0
Mean	**0.59**	**0.41**	
Minimum	**0.46**	**0.2**	
Maximum	**0.8**	**0.54**	
Std. Deviation	**0.11**	**0.11**	
Disagreement			**0.11**

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.15	1	.149	**5.83**
Between Conditions:	0.00	8	0.000	
Residual:	0.20	8	0.026	
Total:	**0.35**	**17**		
Critical F-value with degrees of freedom 1 & 8 at 0.01 level:				**11.26**
Critical F-value with degrees of freedom 1 & 8 at 0.025 level:				**7.57**
Critical F-value with degrees of freedom 1 & 8 at 0.05 level:				**5.32**
Critical F-value with degrees of freedom 1 & 8 at 0.1 level:				**3.46**

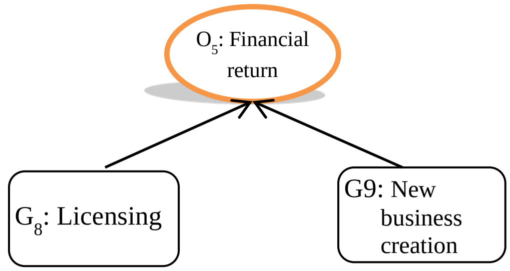
APPENDIX H-2-4: PAIRWISE COMPARISON OF THE UKTT MECHANISM GROUPS WITH RESPECT TO THE UKTT OBJECTIVE 4 “FOSTER CULTURE OF INNOVATION IN UNIVERSITY”



O4: Foster culture of innovation in university	G1: Information dissemination	G2: Networking	G3: Education & Training	G4: Personnel movement	G7: Research	G8: Licensing	G9: New business creation	G10: Institutional infrastructure	Inconsistency
TM6	0.04	0.16	0.12	0.01	0.23	0.29	0.14	0.02	0.08
AR17	0.09	0.15	0.1	0.16	0.28	0.07	0.09	0.05	0.03
TM5	0.23	0.09	0.12	0.1	0.2	0.14	0.07	0.05	0.09
AR21	0.1	0.06	0.03	0.1	0.26	0.25	0.06	0.14	0.03
AR18	0.1	0.15	0.12	0.14	0.17	0.1	0.12	0.11	0.01
AR9	0.05	0.06	0.07	0.07	0.53	0.18	0.01	0.03	0.06
AR14	0.11	0.08	0.2	0.05	0.54	0.01	0	0	0.16
TM1	0.13	0.05	0.1	0.34	0.1	0.06	0.02	0.19	0.05
Mean	**0.11**	**0.1**	**0.11**	**0.12**	**0.29**	**0.14**	**0.06**	**0.07**	
Minimum	**0.04**	**0.05**	**0.03**	**0.01**	**0.1**	**0.01**	**0.02**	**0.19**	
Maximum	**0.23**	**0.16**	**0.2**	**0.34**	**0.54**	**0.29**	**0.14**	**0.19**	
Std. Deviation	**0.05**	**0.04**	**0.05**	**0.09**	**0.15**	**0.09**	**0.05**	**0.06**	
Disagreement									**0.07**

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.28	7	.04	**4.58**
Between Conditions:	0.00	7	0.000	
Residual:	0.42	49	0.009	
Total:	**0.70**	**63**		
Critical F-value with degrees of freedom 7 & 49 at 0.01 level:				**3.03**
Critical F-value with degrees of freedom 7 & 49 at 0.025 level:				**2.56**
Critical F-value with degrees of freedom 7 & 49 at 0.05 level:				**2.2**
Critical F-value with degrees of freedom 7 & 49 at 0.1 level:				**1.84**

APPENDIX H-2-5: PAIRWISE COMPARISON OF THE UKTT MECHANISM GROUPS WITH RESPECT TO THE UKTT OBJECTIVE 5 "FINANCIAL RETURN"



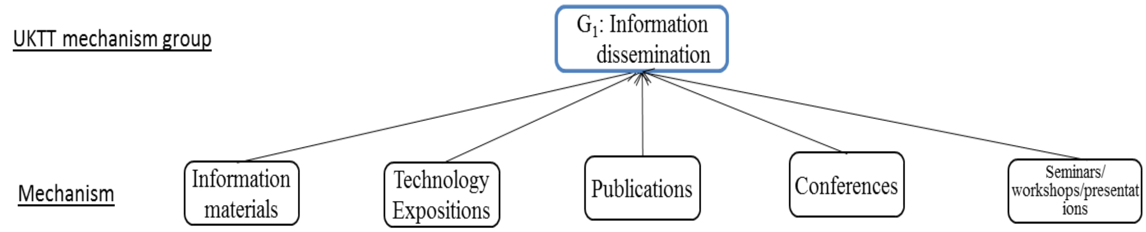
O5: Financial return	G8: Licensing	G9: New business creation	Inconsistency
TM6	0.95	0.05	0
AR17	0.61	0.39	0
TM5	0.55	0.45	0
AR21	0.5	0.5	0
AR9	0.8	0.2	0
AR14	0.91	0.09	0
TM1	0.2	0.8	0
Mean	**0.65**	**0.35**	
Minimum	**0.2**	**0.05**	
Maximum	**0.95**	**0.8**	
Std. Deviation	**0.24**	**0.24**	
Disagreement			**0.24**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.30	1	.297	**2.14**
Between Conditions:	0.00	6	0.000	
Residual:	0.83	6	0.139	
Total:	**1.13**	**13**		
Critical F-value with degrees of freedom 1 & 6 at 0.01 level:				**13.75**
Critical F-value with degrees of freedom 1 & 6 at 0.025 level:				**8.81**
Critical F-value with degrees of freedom 1 & 6 at 0.05 level:				**5.99**
Critical F-value with degrees of freedom 1 & 6 at 0.1 level:				**3.78**

APPENDIX H-3: PAIRWISE COMPARISON OF THE UKTT MECHANISMS.

APPENDIX H-3-1: PAIRWISE COMPARISON OF THE UKTT MECHANISMS IN GROUP 1 "INFORMATION DISSEMINATION"



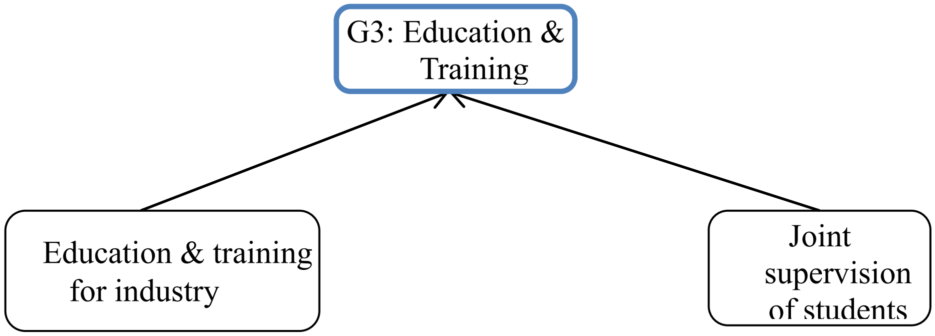
G1: Information dissemination	Informational materials	Technology Expositions	Publications	Conferences	Seminars/Workshops/Presentations	Inconsistency
AR6	0.23	0.21	0.13	0.29	0.14	0.07
AR10	0.17	0.25	0.17	0.17	0.25	0
AR19	0.21	0.18	0.11	0.29	0.21	0.02
AR1	0.17	0.08	0.28	0.28	0.19	0
AR4	0.1	0.24	0.11	0.21	0.35	0.04
AR22	0.22	0.27	0.12	0.12	0.26	0.01
AR21	0.2	0.16	0.2	0.24	0.2	0.03
AR18	0.25	0.2	0.11	0.27	0.18	0.04
AR16	0.26	0.21	0.15	0.15	0.23	0
AR5	0.2	0.36	0.1	0.25	0.09	0.1
TM10	0.06	0.05	0.55	0.19	0.15	0.08
Mean	**0.19**	**0.2**	**0.18**	**0.23**	**0.2**	
Minimum	**0.06**	**0.05**	**0.1**	**0.12**	**0.09**	
Maximum	**0.26**	**0.36**	**0.55**	**0.29**	**0.35**	
Std. Deviation	**0.06**	**0.08**	**0.13**	**0.06**	**0.07**	
Disagreement						**0.08**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.01	4	.003	**.29**
Between Conditions:	0.00	10	0.000	
Residual:	0.37	40	0.009	

Total:	**0.38**	**54**		
Critical F-value with degrees of freedom 4 & 40 at 0.01 level:				**3.83**
Critical F-value with degrees of freedom 4 & 40 at 0.025 level:				**3.13**
Critical F-value with degrees of freedom 4 & 40 at 0.05 level:				**2.61**
Critical F-value with degrees of freedom 4 & 40 at 0.1 level:				**2.09**

APPENDIX H-3-2: PAIRWISE COMPARISON OF THE UKTT MECHANISMS IN GROUP 3 "EDUCATION AND TRAINING"

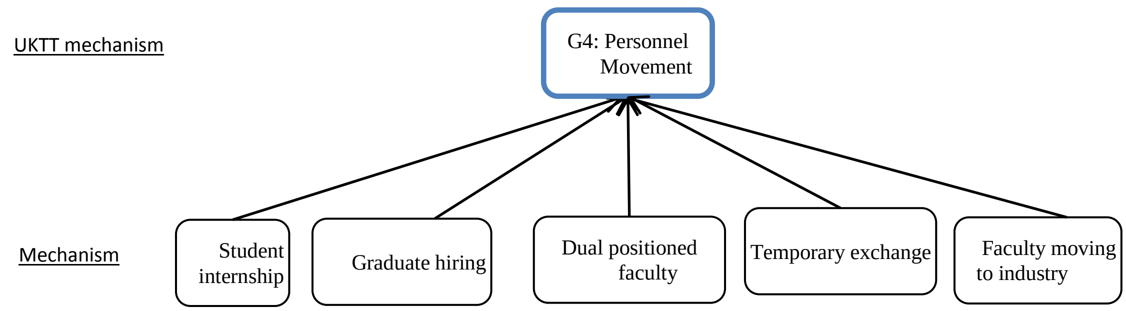


Education and Training	E&T programs for industry	Joint supervision of students	Inconsistency
AR10	0.6	0.4	0
AR19	0.7	0.3	0
TM7	0.5	0.5	0
AR1	0.66	0.34	0
AR4	0.5	0.5	0
AR22	0.5	0.5	0
AR21	0.8	0.2	0
AR18	0.6	0.4	0
AR5	0.46	0.54	0
Mean	**0.59**	**0.41**	
Minimum	**0.46**	**0.2**	
Maximum	**0.8**	**0.54**	
Std. Deviation	**0.11**	**0.11**	
Disagreement			**0.11**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.15	1	.149	**5.83**
Between Conditions:	0.00	8	0.000	
Residual:	0.20	8	0.026	
Total:	**0.35**	**17**		
Critical F-value with degrees of freedom 1 & 8 at 0.01 level:				**11.26**
Critical F-value with degrees of freedom 1 & 8 at 0.025 level:				**7.57**
Critical F-value with degrees of freedom 1 & 8 at 0.05 level:				**5.32**
Critical F-value with degrees of freedom 1 & 8 at 0.1 level:				**3.46**

APPENDIX H-3-3: PAIRWISE COMPARISON OF THE UKTT MECHANISMS IN GROUP 4 "PERSONNEL MOVEMENT"

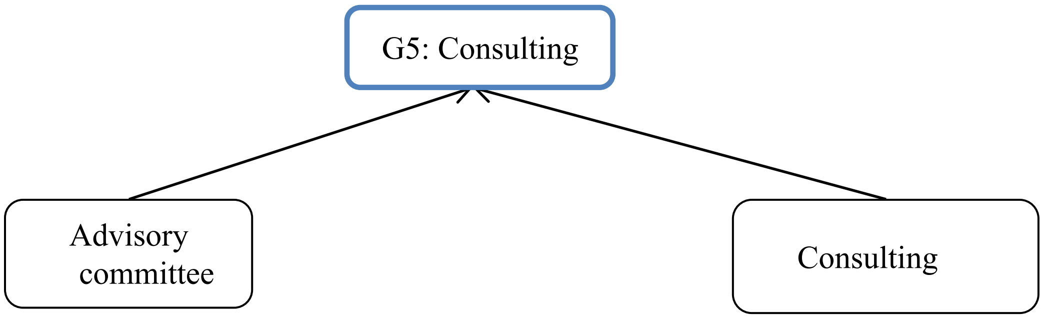


Personnel Movement	Student internship	Graduate hiring	Dual positioned faculty	Temporary personnel exchange	Faculty moving to industry	Inconsistency
AR10	0.19	0.26	0.19	0.27	0.09	0.05
AR19	0.09	0.04	0.35	0.23	0.29	0.08
AR1	0.26	0.43	0.04	0.09	0.18	0
AR4	0.24	0.24	0.26	0.15	0.1	0.12
AR22	0.07	0.25	0.29	0.12	0.27	0.01
AR21	0.2	0.13	0.22	0.23	0.21	0.07
Mean	**0.18**	**0.23**	**0.22**	**0.18**	**0.19**	
Minimum	**0.07**	**0.04**	**0.04**	**0.09**	**0.09**	
Maximum	**0.26**	**0.43**	**0.35**	**0.27**	**0.29**	
Std. Deviation	**0.07**	**0.12**	**0.1**	**0.07**	**0.08**	
Disagreement						**0.09**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.01	4	.003	**.3**
Between Conditions:	0.00	5	0.000	
Residual:	0.24	20	0.012	
Total:	**0.25**	**29**		
Critical F-value with degrees of freedom 4 & 20 at 0.01 level:				**4.43**
Critical F-value with degrees of freedom 4 & 20 at 0.025 level:				**3.51**
Critical F-value with degrees of freedom 4 & 20 at 0.05 level:				**2.87**
Critical F-value with degrees of freedom 4 & 20 at 0.1 level:				**2.25**

APPENDIX H-3-4: PAIRWISE COMPARISON OF THE UKTT MECHANISMS IN GROUP 5 "CONSULTING"

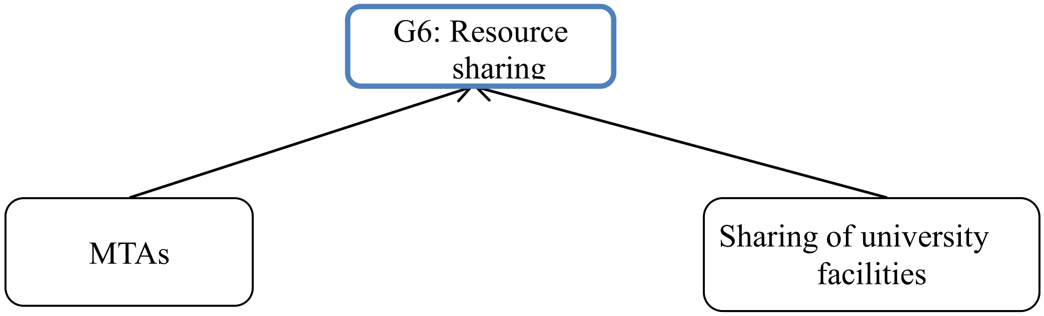


Consulting mechanisms	Advisory committee	Consulting for industry	Inconsistency
AR17	0.3	0.7	0
AR10	0.61	0.39	0
TM7	0.61	0.39	0
AR4	0.5	0.5	0
AR22	0.35	0.65	0
AR21	0.55	0.45	0
AR18	0.3	0.7	0
AR11	0.61	0.39	0
AR16	0.55	0.45	0
Mean	**0.49**	**0.51**	
Minimum	**0.3**	**0.39**	
Maximum	**0.61**	**0.7**	
Std. Deviation	**0.13**	**0.13**	
Disagreement			**0.13**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.00	1	.003	**.09**
Between Conditions:	0.00	8	0.000	
Residual:	0.28	8	0.036	
Total:	**0.29**	**17**		
Critical F-value with degrees of freedom 1 & 8 at 0.01 level:				**11.26**
Critical F-value with degrees of freedom 1 & 8 at 0.025 level:				**7.57**
Critical F-value with degrees of freedom 1 & 8 at 0.05 level:				**5.32**
Critical F-value with degrees of freedom 1 & 8 at 0.1 level:				**3.46**

APPENDIX H-3-5: PAIRWISE COMPARISON OF THE UKTT MECHANISMS IN GROUP 6 “RESOURCE SHARING”

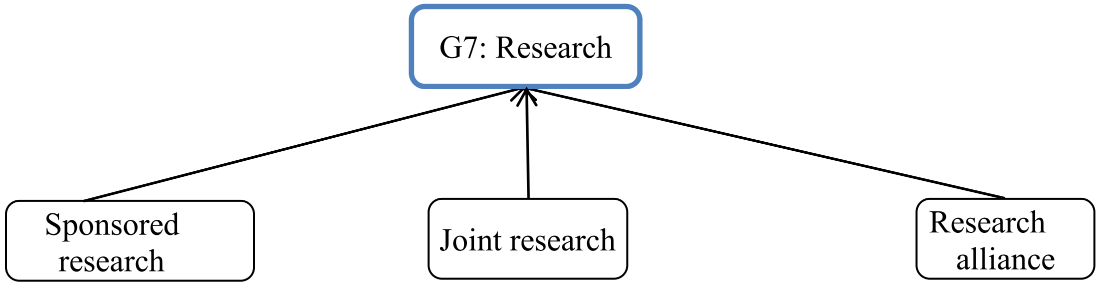


Resource Sharing	MTA	Sharing of university facilities	Inconsistency
AR10	0.4	0.6	0
AR4	0.5	0.5	0
AR11	0.5	0.5	0
Mean	**0.47**	**0.53**	
Minimum	**0.4**	**0.5**	
Maximum	**0.5**	**0.6**	
Std. Deviation	**0.05**	**0.05**	
Disagreement			**0.05**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.01	1	.007	**1**
Between Conditions:	0.00	2	0.000	
Residual:	0.01	2	0.007	
Total:	**0.02**	**5**		
Critical F-value with degrees of freedom 1 & 2 at 0.01 level:				**98.5**
Critical F-value with degrees of freedom 1 & 2 at 0.025 level:				**38.51**
Critical F-value with degrees of freedom 1 & 2 at 0.05 level:				**18.51**
Critical F-value with degrees of freedom 1 & 2 at 0.1 level:				**8.53**

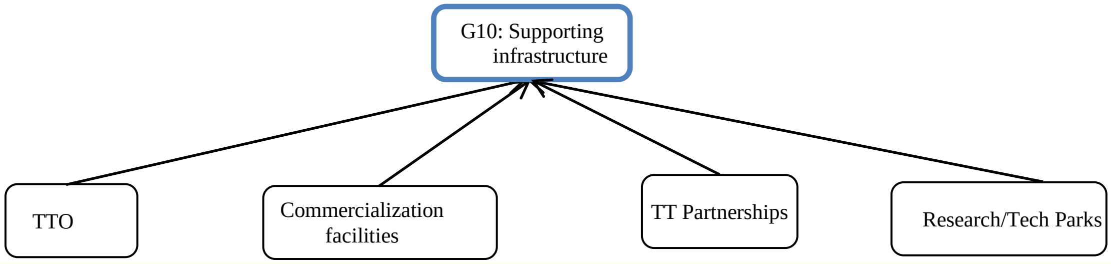
APPENDIX H-3-5: PAIRWISE COMPARISON OF THE UKTT MECHANISMS IN GROUP 7 “RESEARCH”



Research Mechanisms	Industry sponsored research	Joint research	Research alliance/consortium	Inconsistency
AR6	0.44	0.11	0.44	0
AR17	0.17	0.3	0.53	0.02
AR10	0.25	0.38	0.38	0
AR19	0.33	0.33	0.33	0
TM7	0.5	0.24	0.26	0.01
AR1	0.46	0.27	0.27	0
AR4	0.18	0.71	0.11	0
AR22	0.33	0.33	0.33	0
AR18	0.48	0.28	0.24	0.01
AR11	0.21	0.1	0.68	0.03
Mean	**0.34**	**0.31**	**0.35**	
Minimum	**0.17**	**0.1**	**0.11**	
Maximum	**0.5**	**0.71**	**0.68**	
Std. Deviation	**0.12**	**0.16**	**0.15**	
Disagreement				**0.15**

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.01	2	.007	**.2**
Between Conditions:	0.00	9	0.000	
Residual:	0.64	18	0.036	
Total:	**0.65**	**29**		
Critical F-value with degrees of freedom 2 & 18 at 0.01 level:				**6.01**
Critical F-value with degrees of freedom 2 & 18 at 0.025 level:				**4.56**
Critical F-value with degrees of freedom 2 & 18 at 0.05 level:				**3.55**
Critical F-value with degrees of freedom 2 & 18 at 0.1 level:				**2.62**

APPENDIX H-3-8: PAIRWISE COMPARISON OF THE UKTT MECHANISMS IN GROUP 10 "SUPPORTING INFRASTRUCTURE"

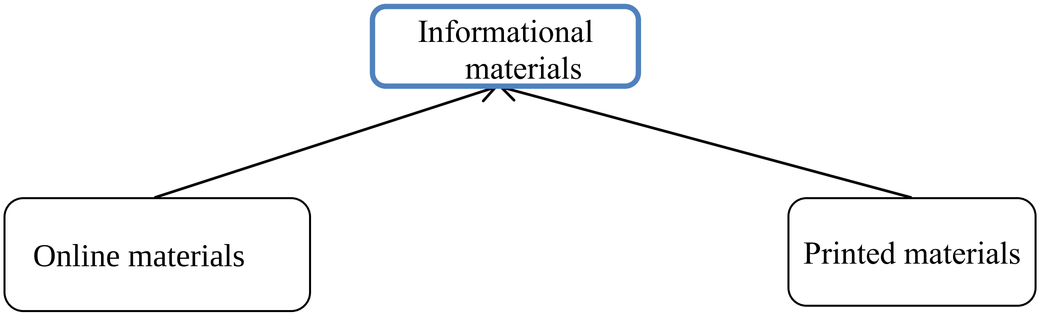


Supporting infrastructure mechanisms	TTO	Tech commercialization support facilities	Tech transfer partnerships	Research/Tech/Science park	Inconsistency
TM6	0.37	0.37	0.11	0.14	0
AR6	0.36	0.21	0.29	0.13	0.06
TM2	0.47	0.26	0.06	0.21	0
AR17	0.13	0.17	0.28	0.42	0.02
AR10	0.33	0.35	0.23	0.09	0.04
AR1	0.23	0.37	0.13	0.27	0
AR4	0.47	0.18	0.19	0.15	0.07
AR22	0.36	0.15	0.17	0.32	0.01
AR21	0.25	0.21	0.35	0.2	0.02
AR18	0.16	0.24	0.27	0.33	0
AR9	0.18	0.36	0.41	0.06	0.03
AR11	0.1	0.3	0.3	0.3	0
AR16	0.24	0.25	0.26	0.25	0
AR8	0.16	0.44	0.15	0.25	0.02
AR5	0.23	0.25	0.3	0.22	0.05
TM10	0.7	0.15	0.01	0.14	0.07
Mean	**0.29**	**0.27**	**0.22**	**0.22**	
Minimum	**0.1**	**0.15**	**0.01**	**0.06**	
Maximum	**0.7**	**0.44**	**0.41**	**0.42**	
Std. Deviation	**0.15**	**0.09**	**0.11**	**0.09**	
Disagreement					**0.11**

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.07	3	.024	**1.32**
Between Conditions:	0.00	15	0.000	
Residual:	0.81	45	0.018	
Total:	**0.88**	**63**		
Critical F-value with degrees of freedom 3 & 45 at 0.01 level:				**4.25**
Critical F-value with degrees of freedom 3 & 45 at 0.025 level:				**3.42**
Critical F-value with degrees of freedom 3 & 45 at 0.05 level:				**2.81**
Critical F-value with degrees of freedom 3 & 45 at 0.1 level:				**2.21**

APPENDIX H-4: PAIRWISE COMPARISON OF THE UKTT MECHANISM INDICATORS

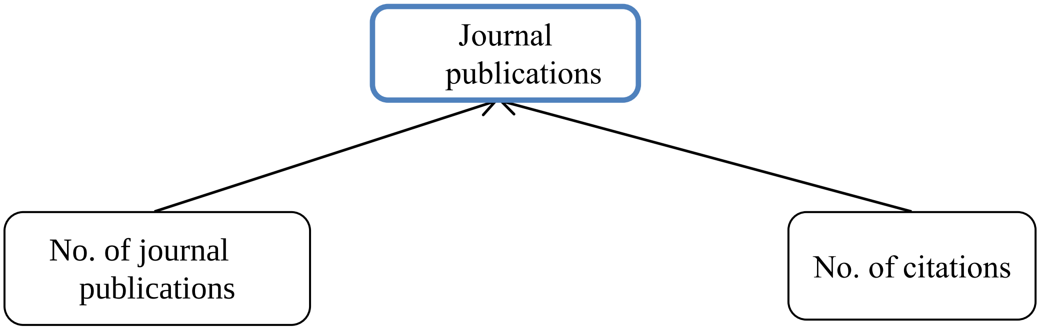
APPENDIX H-4-1: PAIRWISE COMPARISON OF THE INDICATORS OF MECHANISM “INFORMATIONAL MATERIALS”



Indicator - Informational materials	Online materials	Printed materials	Inconsistency
AR6	0.5	0.5	0
AR10	0.8	0.2	0
AR19	0.61	0.39	0
AR1	0.5	0.5	0
AR4	0.58	0.42	0
AR21	0.1	0.9	0
AR18	0.3	0.7	0
AR16	0.56	0.44	0
AR5	0.4	0.6	0
TM10	0.9	0.1	0
Mean	**0.52**	**0.48**	
Minimum	**0.1**	**0.1**	
Maximum	**0.9**	**0.9**	
Std. Deviation	**0.22**	**0.22**	
Disagreement			**0.22**

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.01	1	.013	**.12**
Between Conditions:	0.00	9	0.000	
Residual:	0.95	9	0.106	
Total:	**0.96**	**19**		
Critical F-value with degrees of freedom 1 & 9 at 0.01 level:				**10.56**
Critical F-value with degrees of freedom 1 & 9 at 0.025 level:				**7.21**
Critical F-value with degrees of freedom 1 & 9 at 0.05 level:				**5.12**
Critical F-value with degrees of freedom 1 & 9 at 0.1 level:				**3.36**

APPENDIX H-4-2: PAIRWISE COMPARISON OF THE INDICATORS OF MECHANISM “JOURNAL PUBLICATIONS”

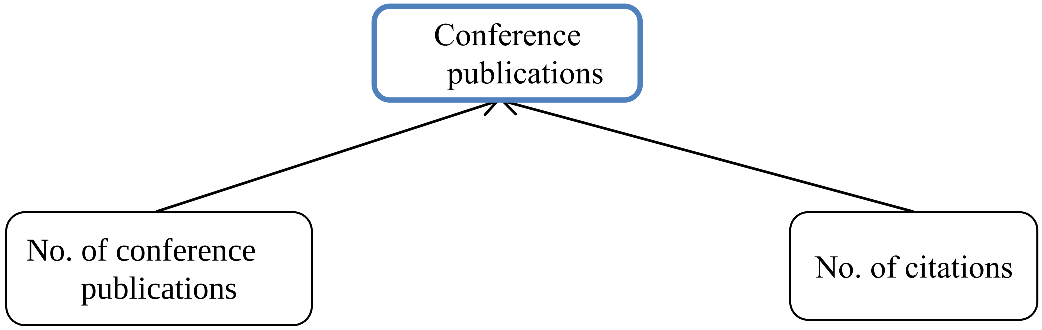


Indicator - Publications	Number of journal publications	Number of journal paper citations	Inconsistency
AR6	0.8	0.2	0
AR10	0.3	0.7	0
AR19	0.65	0.35	0
AR1	0.6	0.4	0
AR4	0.3	0.7	0
AR22	0.3	0.7	0
AR21	0.94	0.06	0
AR18	0.8	0.2	0
AR16	0.5	0.5	0
AR5	0.53	0.47	0
TM10	0.6	0.4	0
Mean	**0.57**	**0.43**	
Minimum	**0.3**	**0.06**	
Maximum	**0.94**	**0.7**	
Std. Deviation	**0.21**	**0.21**	
Disagreement			**0.21**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.12	1	.122	**1.28**
Between Conditions:	0.00	10	0.000	
Residual:	0.95	10	0.095	
Total:	**1.07**	**21**		
Critical F-value with degrees of freedom 1 & 10 at 0.01 level:				**10.04**
Critical F-value with degrees of freedom 1 & 10 at 0.025 level:				**6.94**
Critical F-value with degrees of freedom 1 & 10 at 0.05 level:				**4.96**
Critical F-value with degrees of freedom 1 & 10 at 0.1 level:				**3.29**

APPENDIX H-4-3: PAIRWISE COMPARISON OF THE INDICATORS OF MECHANISM "CONFERENCE PUBLICATIONS"

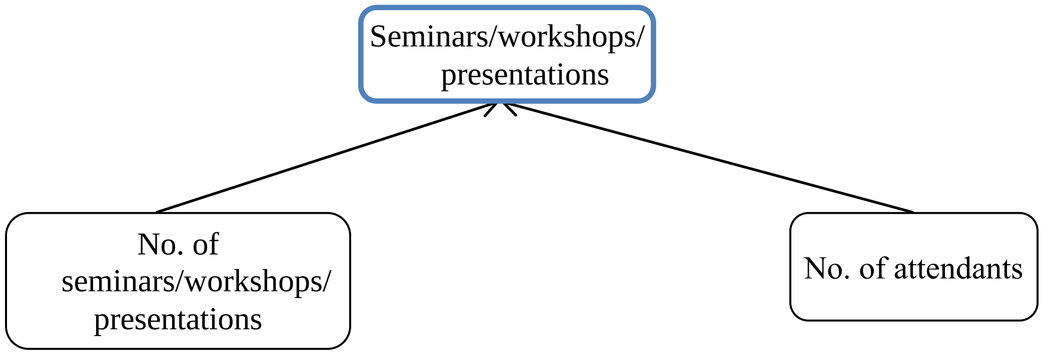


Indicator - Conferences	Number of conference papers	Number of conference paper citations	Inconsistency
AR6	0.8	0.2	0
AR10	0.3	0.7	0
AR19	0.81	0.19	0
AR1	0.75	0.25	0
AR4	0.3	0.7	0
AR22	0.3	0.7	0
AR21	0.91	0.09	0
AR18	0.8	0.2	0
AR16	0.5	0.5	0
AR5	0.45	0.55	0
TM10	0.7	0.3	0
Mean	**0.6**	**0.4**	
Minimum	**0.3**	**0.09**	
Maximum	**0.91**	**0.7**	
Std. Deviation	**0.22**	**0.22**	
Disagreement			**0.22**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.23	1	.228	**2.05**
Between Conditions:	0.00	10	0.000	
Residual:	1.11	10	0.111	
Total:	**1.34**	**21**		
Critical F-value with degrees of freedom 1 & 10 at 0.01 level:				**10.04**
Critical F-value with degrees of freedom 1 & 10 at 0.025 level:				**6.94**
Critical F-value with degrees of freedom 1 & 10 at 0.05 level:				**4.96**
Critical F-value with degrees of freedom 1 & 10 at 0.1 level:				**3.29**

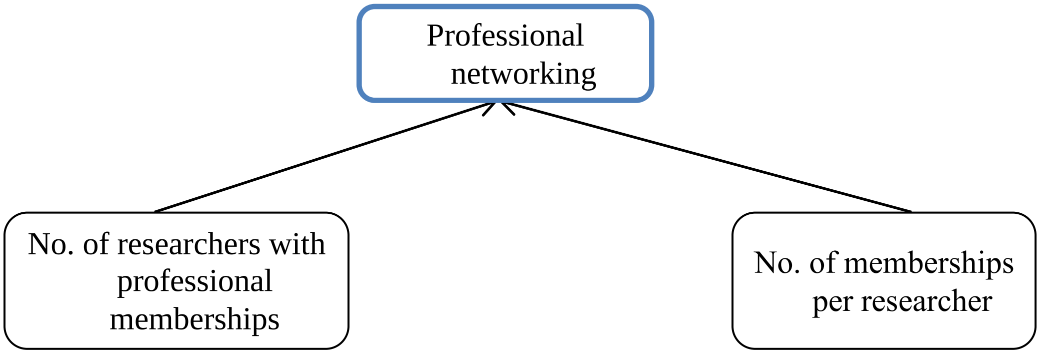
APPENDIX H-4-4: PAIRWISE COMPARISON OF THE INDICATORS OF MECHANISM "SEMINAR/WORKSHOP/PRESENTATION"



Indicator - Seminars/Workshops/Presentations	Number of seminars/workshops/presentations	Number of attendants	Inconsistency
AR6	0.8	0.2	0
AR10	0.5	0.5	0
AR19	0.39	0.61	0
AR1	0.2	0.8	0
AR4	0.43	0.57	0
AR22	0.3	0.7	0
AR21	0.89	0.11	0
AR18	0.5	0.5	0
AR16	0.5	0.5	0
AR5	0.5	0.5	0
TM10	0.95	0.05	0
Mean	**0.54**	**0.46**	
Minimum	**0.2**	**0.05**	
Maximum	**0.95**	**0.8**	
Std. Deviation	**0.23**	**0.23**	
Disagreement			**0.23**

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.04	1	.038	**.34**
Between Conditions:	0.00	10	0.000	
Residual:	1.14	10	0.114	
Total:	**1.18**	**21**		
Critical F-value with degrees of freedom 1 & 10 at 0.01 level:				**10.04**
Critical F-value with degrees of freedom 1 & 10 at 0.025 level:				**6.94**
Critical F-value with degrees of freedom 1 & 10 at 0.05 level:				**4.96**
Critical F-value with degrees of freedom 1 & 10 at 0.1 level:				**3.29**

APPENDIX H-4-5: PAIRWISE COMPARISON OF THE INDICATORS OF MECHANISM "PROFESSIONAL NETWORKING"

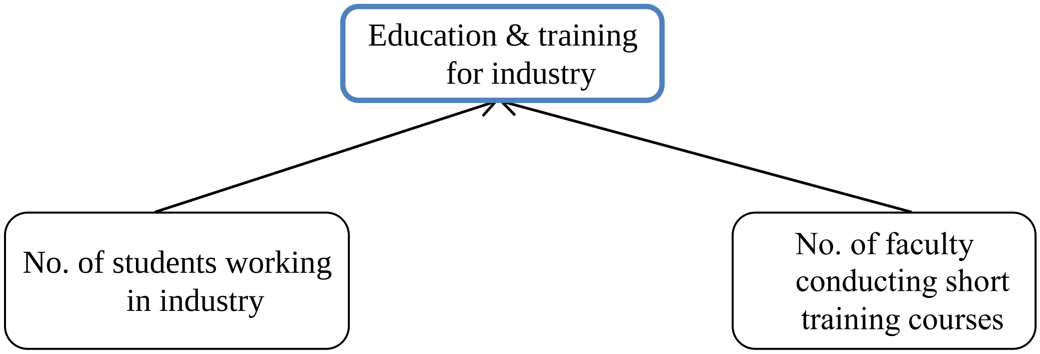


Professional Networking	Number of researchers with professional memberships	Number of memberships per researcher	Inconsistency
TM2	0.5	0.5	0
AR10	0.5	0.5	0
AR1	0.6	0.4	0
AR4	0.62	0.38	0
AR21	0.5	0.5	0
AR18	0.5	0.5	0
AR16	0.6	0.4	0
TM10	0.7	0.3	0
Mean	**0.57**	**0.43**	
Minimum	**0.5**	**0.3**	
Maximum	**0.7**	**0.5**	
Std. Deviation	**0.07**	**0.07**	
Disagreement			**0.07**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.07	1	.068	**5.83**
Between Conditions:	0.00	7	0.000	
Residual:	0.08	7	0.012	
Total:	**0.15**	**15**		
Critical F-value with degrees of freedom 1 & 7 at 0.01 level:				**12.25**
Critical F-value with degrees of freedom 1 & 7 at 0.025 level:				**8.07**
Critical F-value with degrees of freedom 1 & 7 at 0.05 level:				**5.59**
Critical F-value with degrees of freedom 1 & 7 at 0.1 level:				**3.59**

APPENDIX H-4-6: PAIRWISE COMPARISON OF THE INDICATORS OF MECHANISM “EDUCATION&TRAINING FOR INDUSTRY”

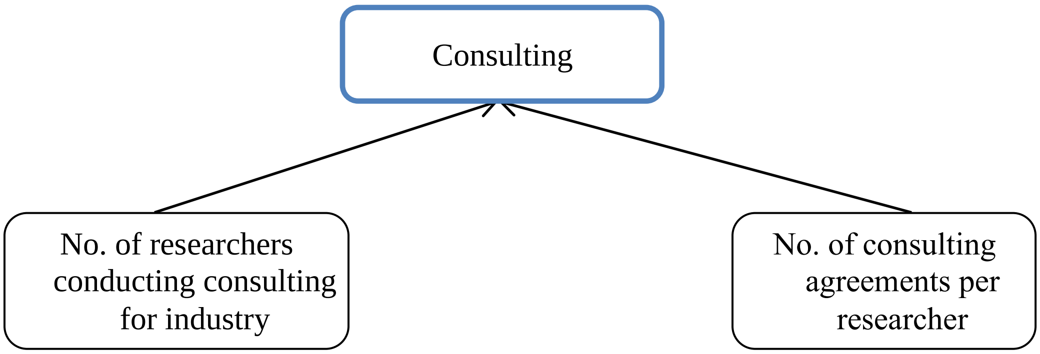


Education & Training for industry	Number of students currently working in industry	Number of faculty conducting short training courses	Inconsistency
AR10	0.4	0.6	0
AR19	0.23	0.77	0
TM7	0.8	0.2	0
AR1	0.83	0.17	0
AR4	0.5	0.5	0
AR22	0.5	0.5	0
AR21	0.26	0.74	0
AR18	0.3	0.7	0
AR5	0.52	0.48	0
Mean	**0.48**	**0.52**	
Minimum	**0.23**	**0.17**	
Maximum	**0.83**	**0.77**	
Std. Deviation	**0.2**	**0.2**	
Disagreement			**0.2**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.01	1	.006	**.06**
Between Conditions:	0.00	8	0.000	
Residual:	0.75	8	0.094	
Total:	**0.76**	**17**		
Critical F-value with degrees of freedom 1 & 8 at 0.01 level:				**11.26**
Critical F-value with degrees of freedom 1 & 8 at 0.025 level:				**7.57**
Critical F-value with degrees of freedom 1 & 8 at 0.05 level:				**5.32**
Critical F-value with degrees of freedom 1 & 8 at 0.1 level:				**3.46**

APPENDIX H-4-7: PAIRWISE COMPARISON OF THE INDICATORS OF MECHANISM “CONSULTING”

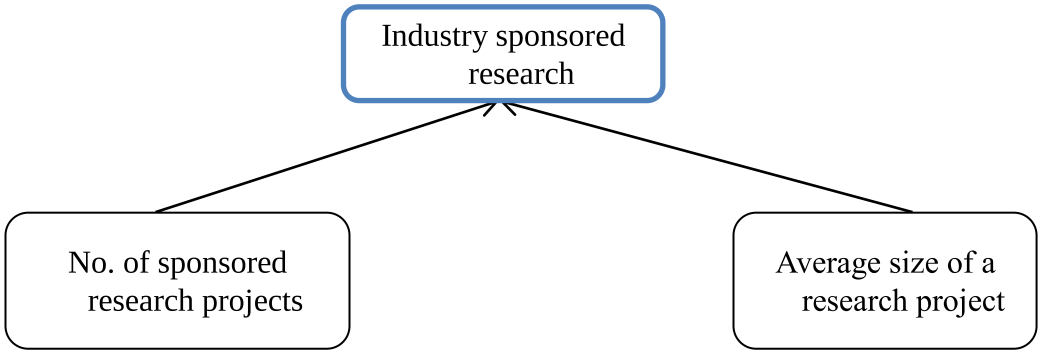


Consulting	Number of faculty conducting consulting for industry	Number of consulting agreements per researcher	Inconsistency
AR17	0.7	0.3	0
TM7	0.87	0.13	0
AR4	0.7	0.3	0
AR22	0.5	0.5	0
AR21	0.46	0.54	0
AR18	0.7	0.3	0
AR16	0.51	0.49	0
Mean	**0.63**	**0.37**	
Minimum	**0.46**	**0.13**	
Maximum	**0.87**	**0.54**	
Std. Deviation	**0.14**	**0.14**	
Disagreement			**0.14**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.25	1	.252	**5.72**
Between Conditions:	0.00	6	0.000	
Residual:	0.26	6	0.044	
Total:	**0.52**	**13**		
Critical F-value with degrees of freedom 1 & 6 at 0.01 level:				**13.75**
Critical F-value with degrees of freedom 1 & 6 at 0.025 level:				**8.81**
Critical F-value with degrees of freedom 1 & 6 at 0.05 level:				**5.99**
Critical F-value with degrees of freedom 1 & 6 at 0.1 level:				**3.78**

APPENDIX H-4-8: PAIRWISE COMPARISON OF THE INDICATORS OF MECHANISM "INDUSTRY SPONSORED RESEARCH"

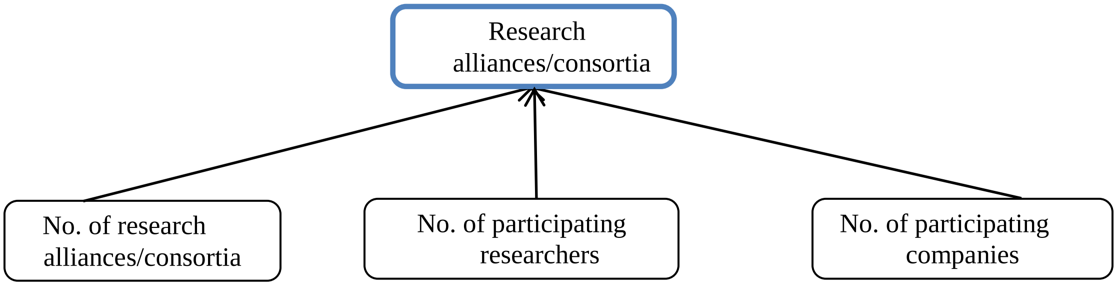


Industry sponsored research	Number of sponsored research projects	Average size of the research projects, $	Inconsistency
AR6	0.55	0.45	0
AR17	0.6	0.4	0
AR10	0.6	0.4	0
AR19	0.51	0.49	0
TM7	0.45	0.55	0
AR1	0.6	0.4	0
AR4	0.4	0.6	0
AR22	0.65	0.35	0
AR18	0.5	0.5	0
Mean	**0.54**	**0.46**	
Minimum	**0.4**	**0.35**	
Maximum	**0.65**	**0.6**	
Std. Deviation	**0.08**	**0.08**	
Disagreement			**0.08**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.03	1	.029	**2.17**
Between Conditions:	0.00	8	0.000	
Residual:	0.11	8	0.013	
Total:	**0.14**	**17**		
Critical F-value with degrees of freedom 1 & 8 at 0.01 level:				**11.26**
Critical F-value with degrees of freedom 1 & 8 at 0.025 level:				**7.57**
Critical F-value with degrees of freedom 1 & 8 at 0.05 level:				**5.32**
Critical F-value with degrees of freedom 1 & 8 at 0.1 level:				**3.46**

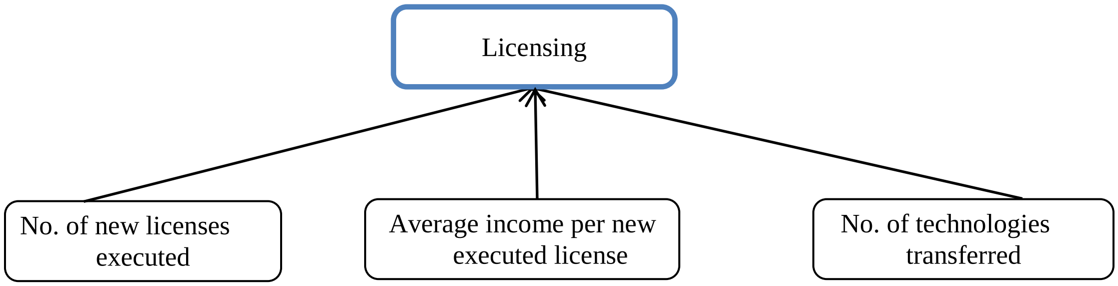
APPENDIX H-4-9: PAIRWISE COMPARISON OF THE INDICATORS OF MECHANISM “RESEARCH ALLIANCE/CONSORTIA”



Research alliances/consortia	Number of Research alliances/consortia	Number of faculty participating in Research alliances/consortia	Number of companies participating in Research alliances/consortia	Inconsistency
AR6	0.47	0.18	0.36	0
AR17	0.18	0.47	0.36	0
AR10	0.25	0.38	0.38	0
AR19	0.33	0.33	0.33	0
TM7	0.33	0.33	0.33	0
AR1	0.1	0.4	0.5	0
AR4	0.36	0.49	0.15	0
AR22	0.33	0.33	0.33	0
AR18	0.35	0.29	0.36	0.01
Mean	**0.3**	**0.36**	**0.34**	
Minimum	**0.1**	**0.18**	**0.15**	
Maximum	**0.47**	**0.49**	**0.5**	
Std. Deviation	**0.1**	**0.09**	**0.08**	
Disagreement				**0.09**

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.02	2	.008	**.56**
Between Conditions:	0.00	8	0.000	
Residual:	0.23	16	0.014	
Total:	**0.25**	**26**		
Critical F-value with degrees of freedom 2 & 16 at 0.01 level:				**6.23**
Critical F-value with degrees of freedom 2 & 16 at 0.025 level:				**4.69**
Critical F-value with degrees of freedom 2 & 16 at 0.05 level:				**3.63**
Critical F-value with degrees of freedom 2 & 16 at 0.1 level:				**2.67**

APPENDIX H-4-10: PAIRWISE COMPARISON OF THE INDICATORS OF MECHANISM "LICENSING"

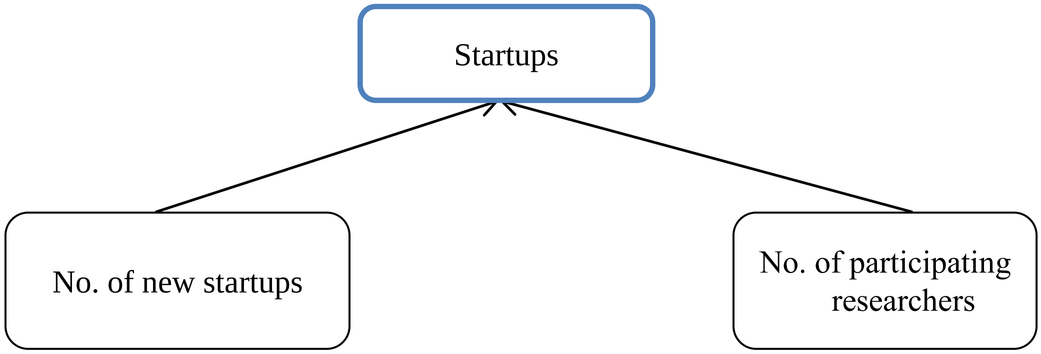


Licensing	Number of new license executed	Average income per executed license	Number of technologies transferred	Inconsistency
TM6	0.45	0.12	0.43	0
TM2	0.32	0.22	0.46	0
AR17	0.26	0.2	0.54	0
AR10	0.36	0.47	0.18	0
TM7	0.04	0.65	0.31	0
AR1	0.3	0.54	0.16	0
AR15	0.22	0.12	0.66	0.02
AR4	0.21	0.35	0.44	0.02
AR22	0.25	0.53	0.22	0
AR18	0.39	0.11	0.5	0
AR9	0.21	0.05	0.74	0.09
AR11	0.24	0.09	0.67	0
Mean	**0.27**	**0.29**	**0.44**	
Minimum	**0.04**	**0.05**	**0.16**	
Maximum	**0.45**	**0.65**	**0.74**	
Std. Deviation	**0.1**	**0.2**	**0.19**	
Disagreement				**0.16**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.22	2	.108	**2.31**
Between Conditions:	0.00	11	0.000	
Residual:	1.03	22	0.047	
Total:	**1.24**	**35**		
Critical F-value with degrees of freedom 2 & 22 at 0.01 level:				**5.72**
Critical F-value with degrees of freedom 2 & 22 at 0.025 level:				**4.38**
Critical F-value with degrees of freedom 2 & 22 at 0.05 level:				**3.44**
Critical F-value with degrees of freedom 2 & 22 at 0.1 level:				**2.56**

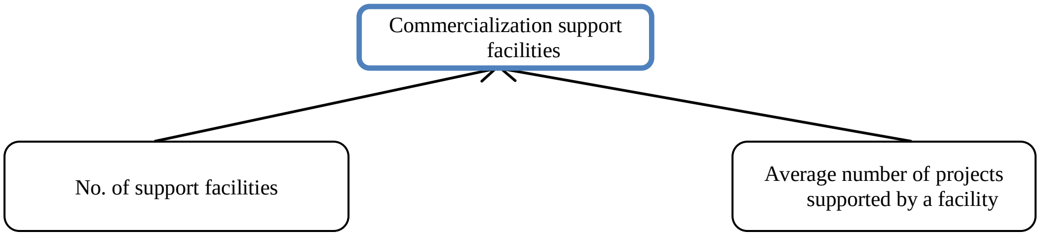
APPENDIX H-4-11: PAIRWISE COMPARISON OF THE INDICATORS OF MECHANISM "STARTUPS"



Startups	Number of new startups	Number of faculty involved in start-up business	Inconsistency
TM3	0.75	0.25	0
AR17	0.7	0.3	0
AR10	0.5	0.5	0
AR19	0.5	0.5	0
TM7	0.7	0.3	0
AR1	0.4	0.6	0
AR4	0.8	0.2	0
AR22	0.75	0.25	0
AR21	0.67	0.33	0
AR18	0.3	0.7	0
AR9	0.89	0.11	0
AR11	0.5	0.5	0
AR16	0.51	0.49	0
AR8	0.7	0.3	0
TM10	0.9	0.1	0
Mean	**0.64**	**0.36**	
Minimum	**0.3**	**0.1**	
Maximum	**0.9**	**0.7**	
Std. Deviation	**0.17**	**0.17**	
Disagreement			**0.17**

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.57	1	.571	**9.08**
Between Conditions:	0.00	14	0.000	
Residual:	0.88	14	0.063	
Total:	**1.45**	**29**		
Critical F-value with degrees of freedom 1 & 14 at 0.01 level:				**8.86**
Critical F-value with degrees of freedom 1 & 14 at 0.025 level:				**6.3**
Critical F-value with degrees of freedom 1 & 14 at 0.05 level:				**4.6**
Critical F-value with degrees of freedom 1 & 14 at 0.1 level:				**3.1**

APPENDIX H-4-12: PAIRWISE COMPARISON OF THE INDICATORS OF MECHANISM “COMMERCIALIZATION SUPPORT FACILITIES”

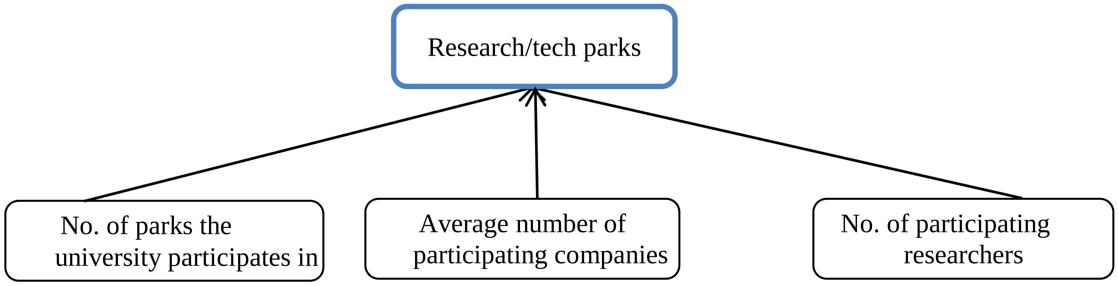


Indicator - Tech commercialization support facilities	Number of tech commercialization support facilities	Average number of projects supported by this facility	Inconsistency
TM6	0.2	0.8	0
AR6	0.9	0.1	0
TM2	0.5	0.5	0
AR17	0.2	0.8	0
AR10	0.5	0.5	0
AR1	0.3	0.7	0
AR1	0.2	0.8	0
AR4	0.3	0.7	0
AR22	0.5	0.5	0
AR21	0.22	0.78	0
AR18	0.8	0.2	0
AR9	0.26	0.74	0
AR11	0.55	0.45	0
AR16	0.53	0.47	0
AR8	0.3	0.7	0
AR5	0.64	0.36	0
TM10	0.05	0.95	0
Mean	**0.41**	**0.59**	
Minimum	**0.05**	**0.1**	
Maximum	**0.9**	**0.95**	
Std. Deviation	**0.22**	**0.22**	
Disagreement			**0.22**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	**Sum of Square**	**Deg. of freedom**	**Mean Square**	**F-test value**
Between Subjects:	0.28	1	.283	**2.63**
Between Conditions:	0.00	16	0.000	
Residual:	1.72	16	0.108	
Total:	**2.00**	**33**		
Critical F-value with degrees of freedom 1 & 16 at 0.01 level:				**8.53**
Critical F-value with degrees of freedom 1 & 16 at 0.025 level:				**6.12**
Critical F-value with degrees of freedom 1 & 16 at 0.05 level:				**4.49**
Critical F-value with degrees of freedom 1 & 16 at 0.1 level:				**3.05**

APPENDIX H-4-13: PAIRWISE COMPARISON OF THE INDICATORS OF "RESEARCH/TECH PARKS" MECHANISM



Research/Tech/Science park	Number of parks the university participates in	Average number of companies participate in a park	Number of faculty members doing research in the parks	Inconsistency
AR6	0.57	0.11	0.32	0.02
TM2	0.05	0.47	0.47	0
AR17	0.18	0.41	0.41	0
AR10	0.15	0.46	0.39	0.01
AR1	0.04	0.74	0.23	0
AR1	0.23	0.23	0.54	0
AR22	0.33	0.33	0.33	0
AR18	0.9	0.04	0.06	0.01
AR9	0.11	0.57	0.32	0.09
AR11	0.37	0.25	0.38	0.01
AR16	0.32	0.37	0.31	0
AR8	0.14	0.34	0.53	0
AR5	0.28	0.4	0.32	0
TM10	0.04	0.83	0.13	0.13
Mean	**0.27**	**0.4**	**0.33**	
Minimum	**0.04**	**0.04**	**0.06**	
Maximum	**0.9**	**0.83**	**0.54**	
Std. Deviation	**0.23**	**0.21**	**0.13**	
Disagreement				**0.19**

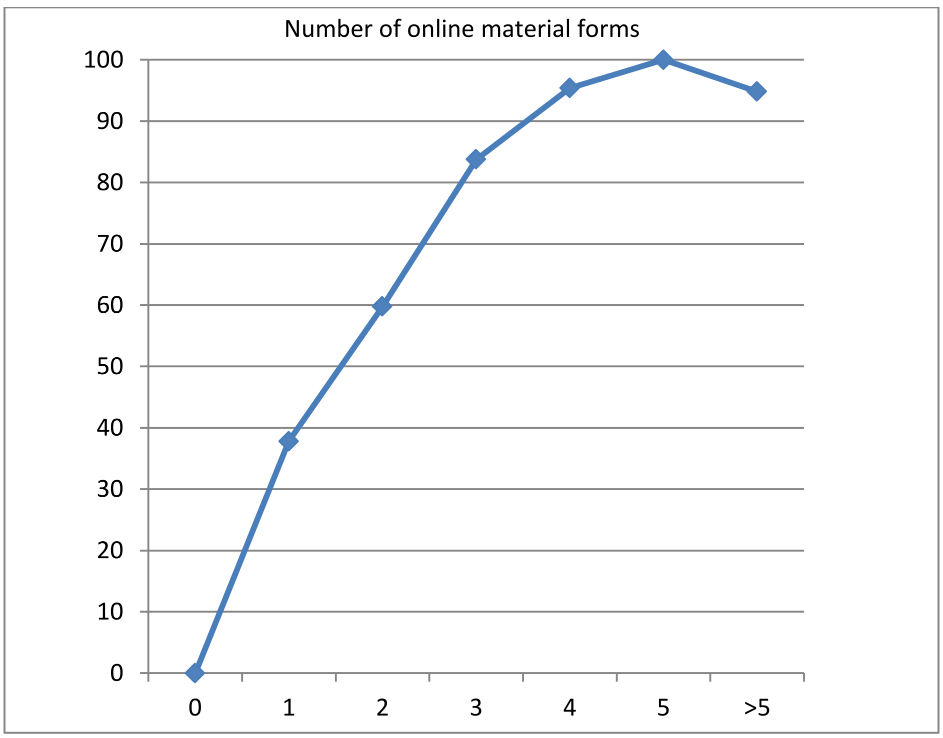
The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.12	2	.061	**1.01**
Between Conditions:	0.00	13	0.000	
Residual:	1.57	26	0.061	
Total:	**1.70**	**41**		
Critical F-value with degrees of freedom 2 & 26 at 0.01 level:				**5.53**
Critical F-value with degrees of freedom 2 & 26 at 0.025 level:				**4.27**
Critical F-value with degrees of freedom 2 & 26 at 0.05 level:				**3.37**
Critical F-value with degrees of freedom 2 & 26 at 0.1 level:				**2.52**

APPENDIX I: DESIRABILITY CURVES

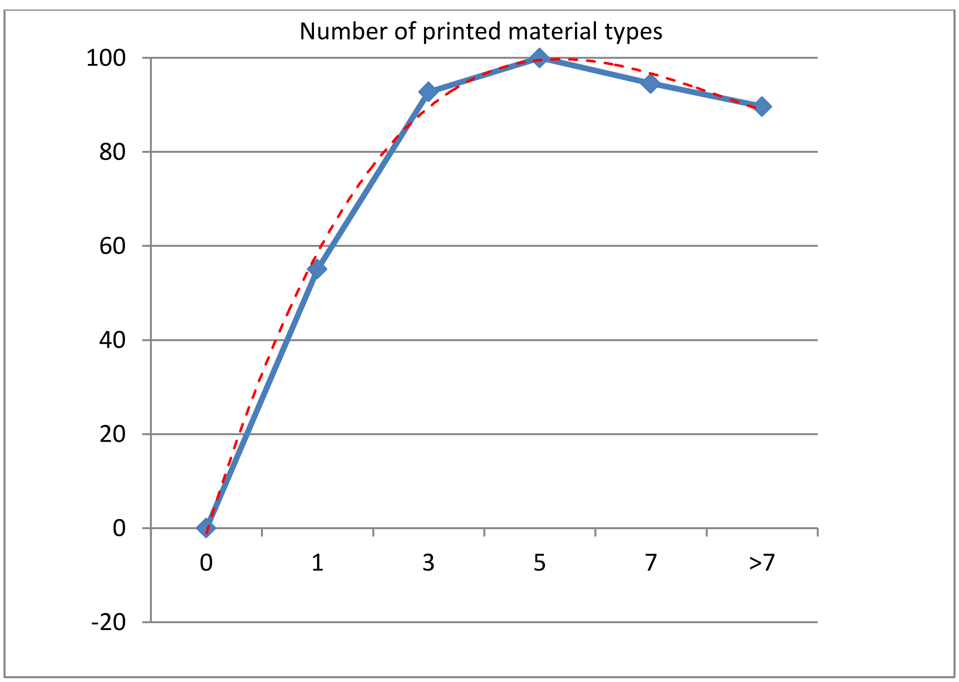
APPENDIX I -1: DESIRABILITY CURVE OF “ONLINE MATERIALS” METRIC

	No. of online material forms						
Expert	*0*	*1*	*2*	*3*	*4*	*5*	*>5*
AR10	0	10	30	50	70	90	100
AR18	0	30	50	70	84	95	49
AR6	0	10	20	30	30	30	30
AR16	0	57	61	58	60	62	60
AR19	0	20	50	100	100	88	81
AR21	0	36	48	59	66	73	81
AR1	0	25	60	80	90	97	100
AR4	0	5	17	36	64	61	59
TM10	0	70	80	100	100	100	100
Mean	0	29	46	65	74	77	73
Normalized mean	0	38	60	84	95	100	95



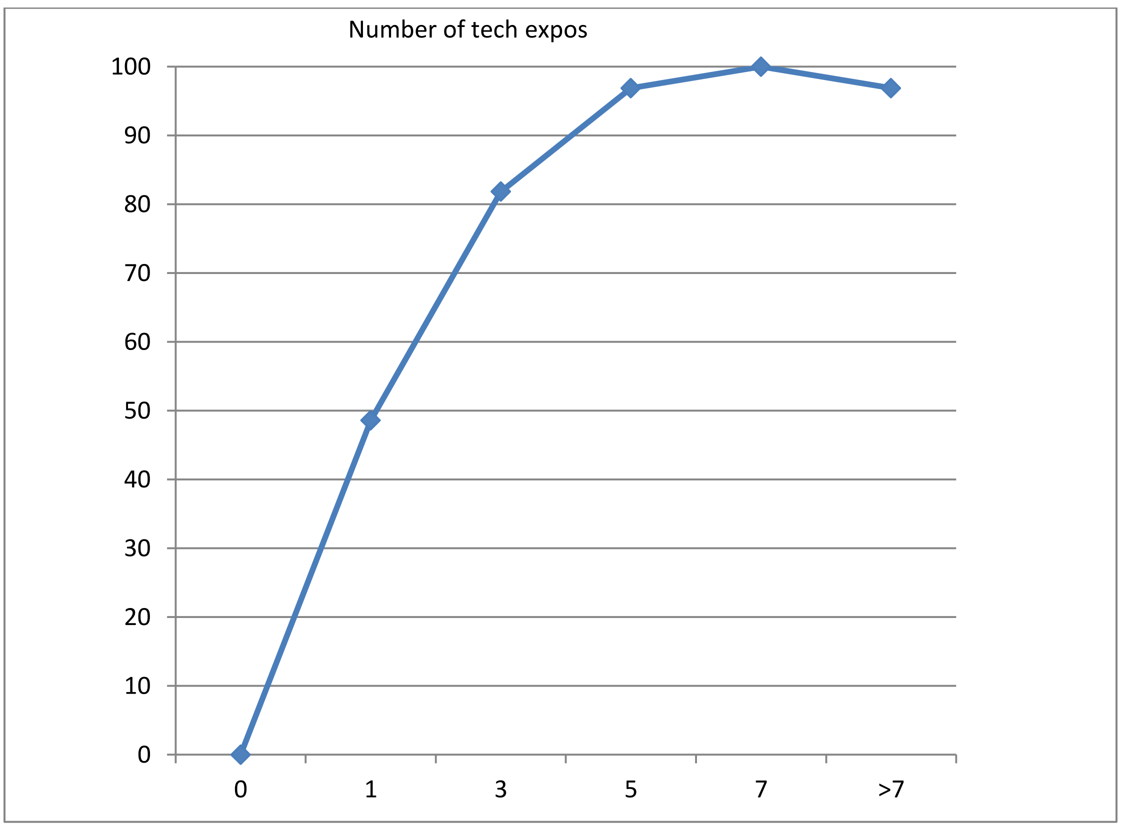
APPENDIX I -2: DESIRABILITY CURVE OF "PRINTED MATERIALS" METRIC

	No. of printed material forms					
Expert	*0*	*1*	*3*	*5*	*7*	*>7*
AR5	37	46	49	49	51	8
AR10	0	10	30	50	80	100
AR18	0	19	41	81	70	35
AR6	0	5	20	20	20	20
AR16	0	64	66	64	64	68
AR19	0	50	100	50	20	20
AR21	0	26	36	42	52	70
AR1	0	50	95	90	80	70
AR4	0	10	34	55	36	12
TM10	0	70	90	100	100	100
Mean	0	34	57	61	58	55
Normalized mean	0	55	93	100	95	90



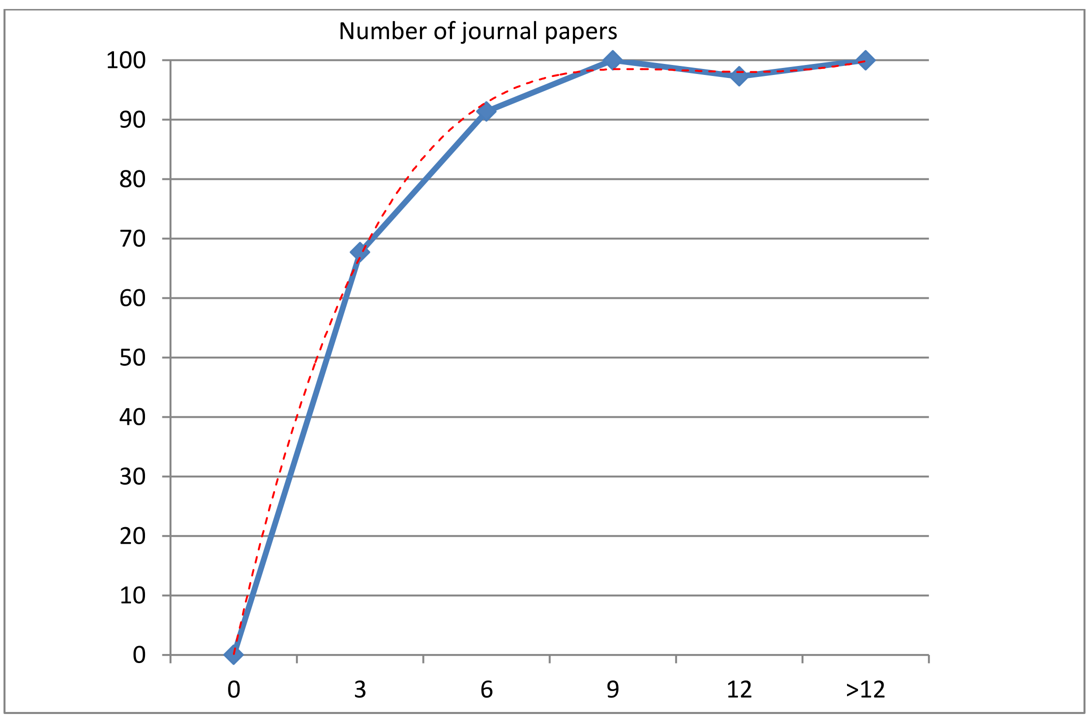
APPENDIX I -3: DESIRABILITY CURVE OF "NUMBER OF TECHNNOLOGY EXPOSITIONS" METRIC

	No. of tech expositions					
Expert	*0*	*1*	*3*	*5*	*7*	*>7*
AR5	0	7	50	70	74	57
AR10	0	20	40	60	80	100
AR18	0	19	62	96	42	20
AR6	0	54	55	56	54	55
AR16	0	70	70	20	20	20
AR19	0	54	65	69	72	74
AR21	0	25	65	85	95	100
AR1	0	28	43	61	74	86
AR4	0	20	50	75	100	80
Mean	0	33	56	66	68	66
Normalized mean	0	49	82	97	100	97



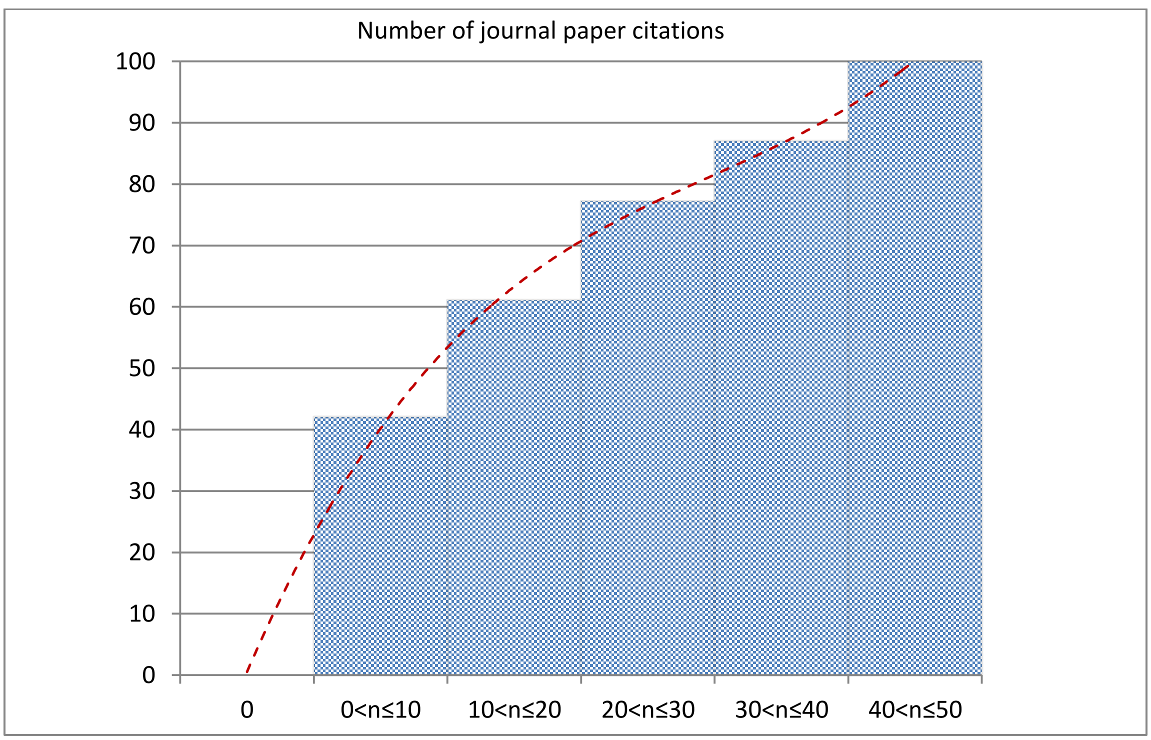
APPENDIX I -4: DESIRABILITY CURVE OF “NUMBER OF JOURNAL PUBLICATIONS” METRIC

	No. of journal papers					
Expert	*0*	*3*	*6*	*9*	*12*	*>12*
AR5	0	25	35	50	15	0
AR10	0	10	30	50	70	100
AR18	0	14	51	80	92	100
AR6	0	20	30	35	39	42
AR16	0	51	54	51	52	54
AR19	0	100	80	30	20	20
AR21	0	43	67	86	93	98
AR1	0	60	90	93	95	100
AR4	0	23	40	54	36	15
TM10	0	80	98	100	100	100
Mean	0	43	58	63	61	63
Normalized	0	68	91	100	97	100



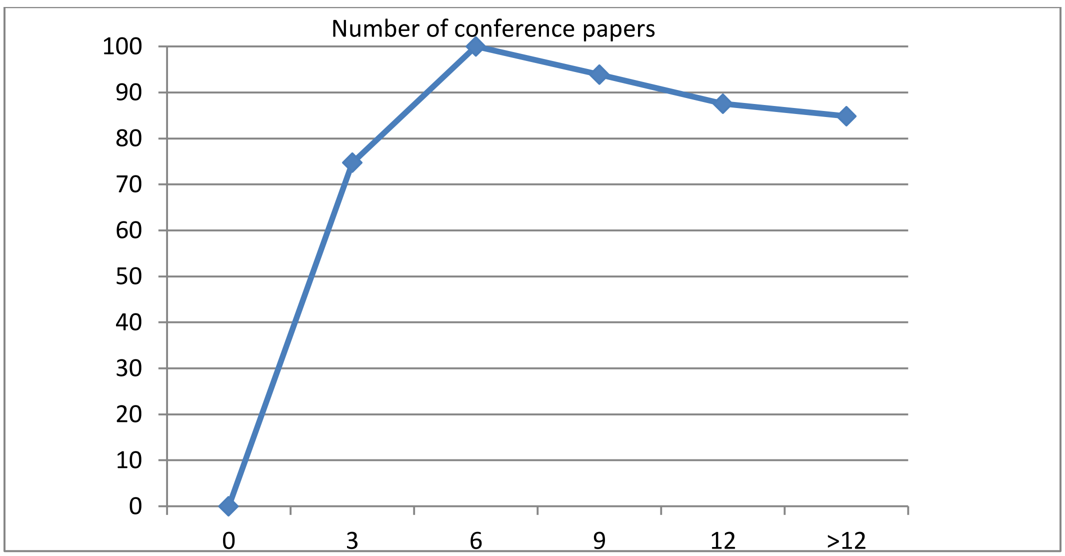
APPENDIX I -5: DESIRABILITY CURVE OF "NUMBER OF CITATIONS TO JOURNAL PAPERS" METRIC

	No. of journal paper citations						
Expert	*0*	*0<n≤10*	*10<n≤20*	*20<n≤30*	*30<n≤40*	*40<n≤50*	*n>50*
AR5	0	46	58	64	64	51	0
AR10	0	20	30	40	50	70	100
AR18	0	20	49	70	78	99	100
AR6	0	10	20	30	40	50	80
AR16	0	53	51	53	53	53	53
AR19	0	10	20	40	60	80	100
AR21	0	35	44	58	67	78	88
AR1	0	80	95	100	100	100	100
AR4	0	34	45	50	56	64	78
TM10	0	30	70	95	100	100	100
Mean	0	32	47	60	67	77	89
Normalized	0	37	53	67	76	87	100



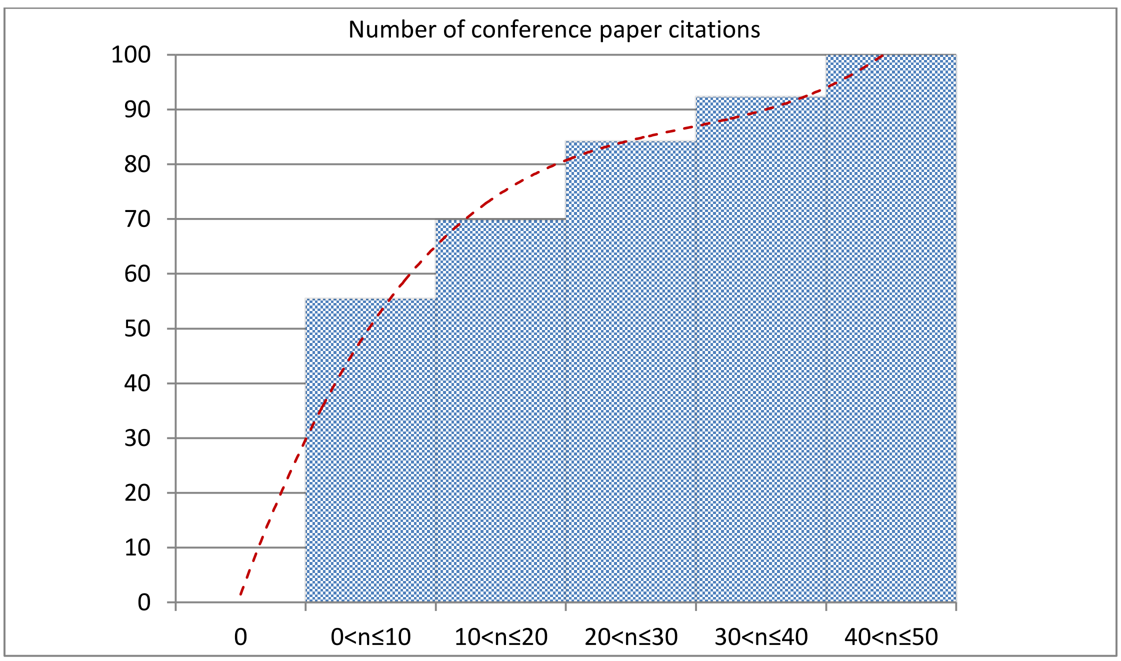
APPENDIX I -6: DESIRABILITY CURVE OF “NUMBER OF CONFERENCE PAPERS” METRIC

	No. of conference papers					
Expert	*0*	*3*	*6*	*9*	*12*	*>12*
AR10	0	10	30	60	80	100
AR18	0	54	98	29	6	0
AR6	0	10	20	20	20	10
AR16	0	54	52	55	53	53
AR19	0	20	10	5	0	0
AR21	0	13	17	21	26	30
AR1	0	80	100	100	95	95
AR4	0	33	47	55	35	14
TM10	0	80	100	100	100	100
Mean	0	39	53	49	46	45
Normalized	0	75	100	94	88	85



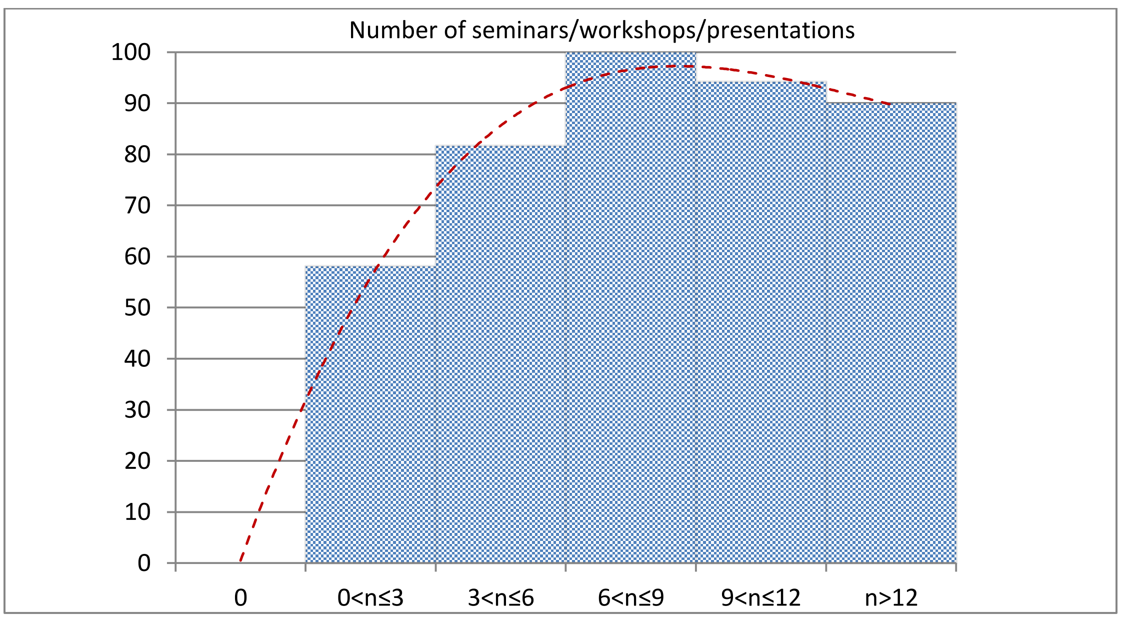
APPENDIX I -7: DESIRABILITY CURVE OF "NUMBER OF CITATIONS TO CONFERENCE PAPERS" METRIC

	No. of conference paper citations						
Expert	*0*	*0<n≤10*	*10<n≤20*	*20<n≤30*	*30<n≤40*	*40<n≤50*	*n>50*
AR10	0	10	20	40	60	80	100
AR18	0	50	75	92	97	100	100
AR6	0	10	13	20	24	30	40
AR16	0	53	52	54	52	54	54
AR19	0	10	20	40	60	80	100
AR21	0	25	34	45	60	71	86
AR1	0	85	98	100	100	100	100
AR4	0	22	35	48	38	25	4
TM10	0	90	100	100	100	100	100
Mean	0	39	50	60	66	71	76
Normalized	0	52	65	79	86	94	100



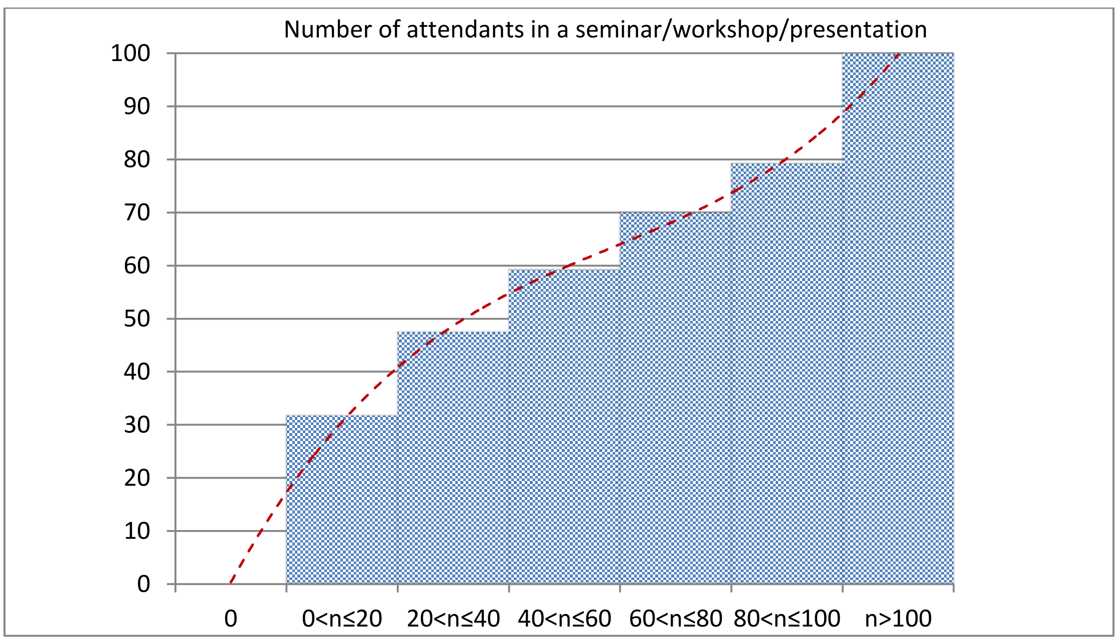
APPENDIX I -8: DESIRABILITY CURVE OF “NUMBER OF WORKSHOPS/SEMINARS/PRESENTATIONS” METRIC

	Number of seminars/workshops/presentations					
Expert	*0*	*0<n≤3*	*3<n≤6*	*6<n≤9*	*9<n≤12*	*n>12*
AR5	0	35	50	50	38	0
AR10	0	10	30	60	80	100
AR18	0	50	82	100	50	18
AR6	0	10	14	20	24	25
AR16	0	61	64	69	71	75
AR19	0	20	20	20	10	5
AR21	0	21	25	33	48	67
AR1	0	80	100	100	90	80
AR4	0	6	22	38	55	71
TM10	0	50	75	100	90	90
Mean	0	34	48	59	56	53
Normalized	0	58	82	100	94	90



APPENDIX I -9: DESIRABILITY CURVE OF "NUMBER OF ATTENDANTS AT WORKSHOPS/SEMINARS/PRESENTATIONS" METRIC

	Number of attendants in a seminar/workshop/presentation						
Expert	*0*	*0<n≤20*	*20<n≤40*	*40<n≤60*	*60<n≤80*	*80<n≤100*	*n>100*
AR18	0	51	70	81	90	96	100
AR6	0	10	20	30	40	50	80
AR16	0	52	55	57	59	61	62
AR19	0	20	40	30	20	20	15
AR21	0	33	42	52	67	80	92
AR1	0	75	95	90	80	70	65
AR4	0	18	43	55	71	83	93
TM10	0	10	20	50	70	90	100
Mean	0	34	48	56	62	69	76
Normalized	0	44	63	73	82	91	100

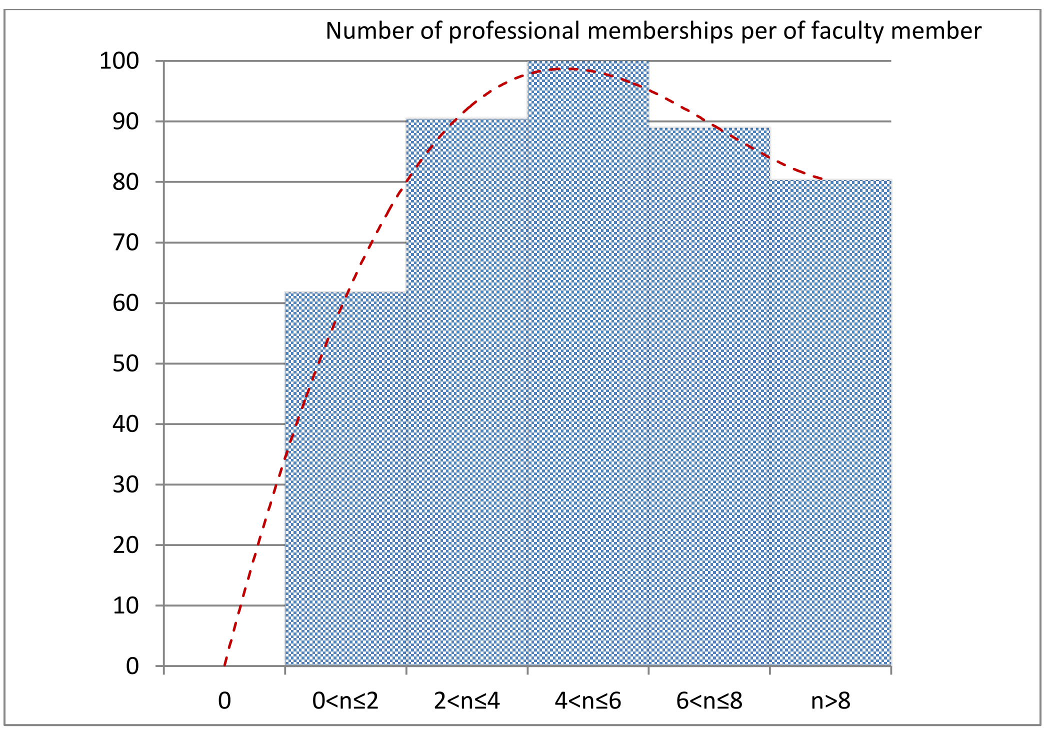


APPENDIX I -10: DESIRABILITY CURVE OF "NUMBER OF FACULTY WITH PROFESSIONAL MEMBERSHIPS" METRIC

	Percentage of faculty with professional memberships					
Expert	*0*	*0<n≤20%*	*20%<n≤40%*	*40%<n≤60%*	*60%<n≤80%*	*80%<n≤100%*
TM2	0	0	0	0	0	100
AR10	0	10	20	30	90	100
AR18	0	10	20	30	70	100
AR16	0	53	56	57	59	61
AR21	0	22	29	31	34	36
AR1	0	40	60	80	90	100
AR4	0	10	36	54	72	89
TM10	0	30	50	80	100	100
Mean	0	22	34	45	64	86
Normalized	0	26	40	53	75	100

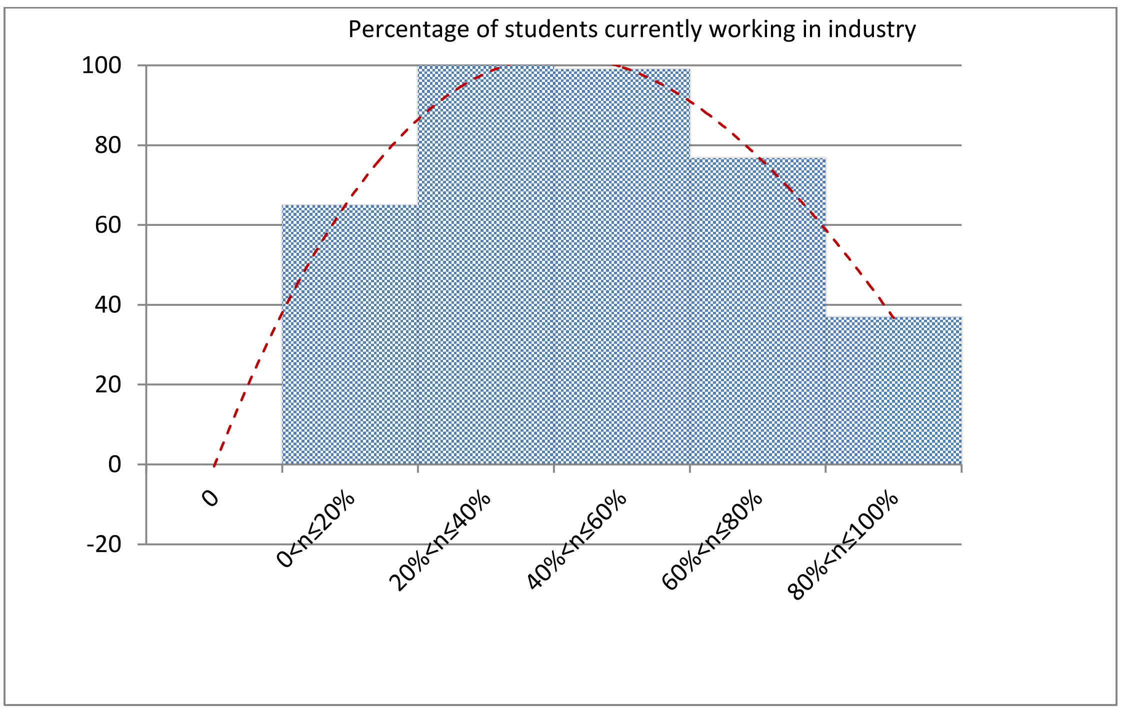
APPENDIX I -11: DESIRABILITY CURVE OF “NUMBER OF PROFESSIONAL MEMBERSHIPS PER FACULTY MEMBER” METRIC

	Number of professional memberships per of faculty member					
Expert	*0*	*0<n≤2*	*2<n≤4*	*4<n≤6*	*6<n≤8*	*n>8*
TM2	0	60	80	90	90	85
AR10	0	10	20	50	90	100
AR18	0	40	80	100	20	0
AR16	0	44	46	49	51	52
AR21	0	9	12	13	16	19
AR1	0	80	95	80	75	60
AR4	0	7	50	52	33	13
TM10	0	80	100	100	100	100
Mean	0	41	60	67	59	54
Normalized	0	62	90	100	89	80



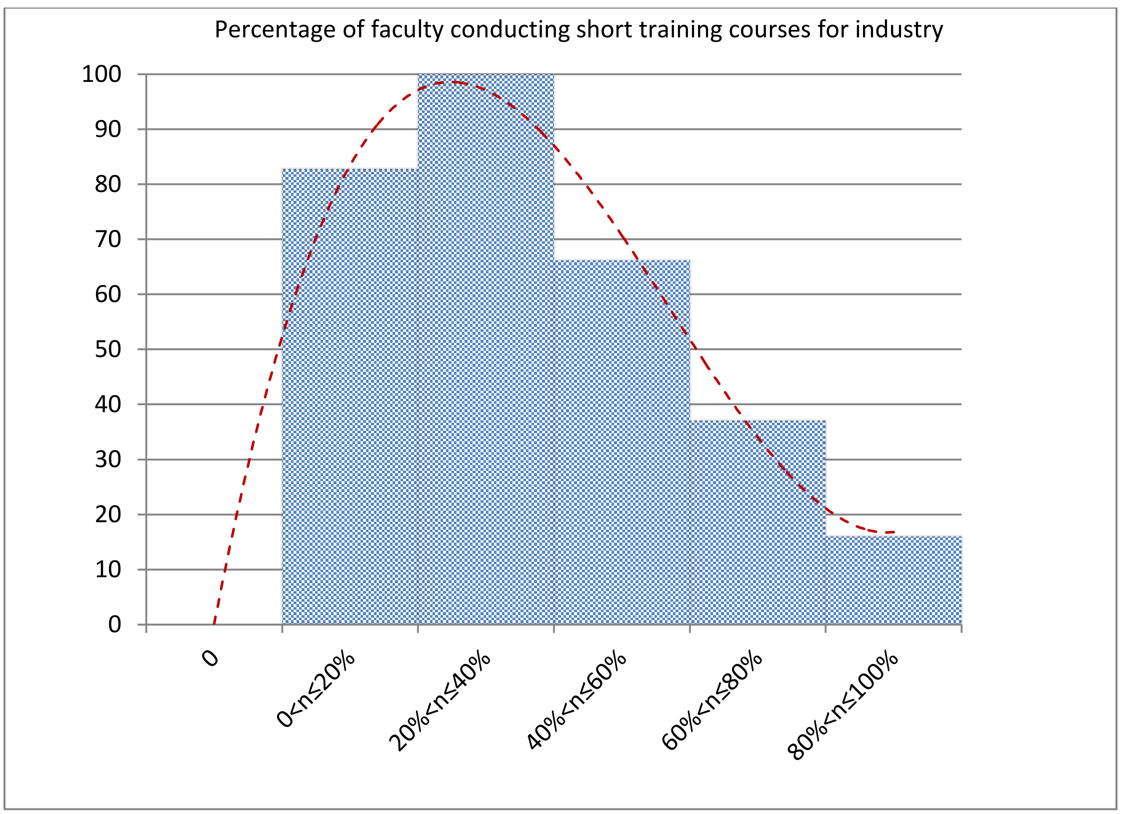
APPENDIX I -12: DESIRABILITY CURVE OF “NUMBER OF STUDENTS CURRENTLY WORKING IN INDUSTRY” METRIC

	Percentage of students currently working in industry					
Expert	*0*	*0<n≤20%*	*20%<n≤40%*	*40%<n≤60%*	*60%<n≤80%*	*80%<n≤100%*
AR5	0	17	38	45	41	7
AR10	0	70	70	60	50	30
AR18	0	20	100	70	20	0
TM7	0	30	20	12	9	4
AR19	0	20	40	100	100	70
AR21	0	7	12	17	25	31
AR1	0	75	90	75	60	10
AR4	0	32	47	34	15	2
Mean	0	34	52	52	40	19
Normalized	0	65	100	99	77	37



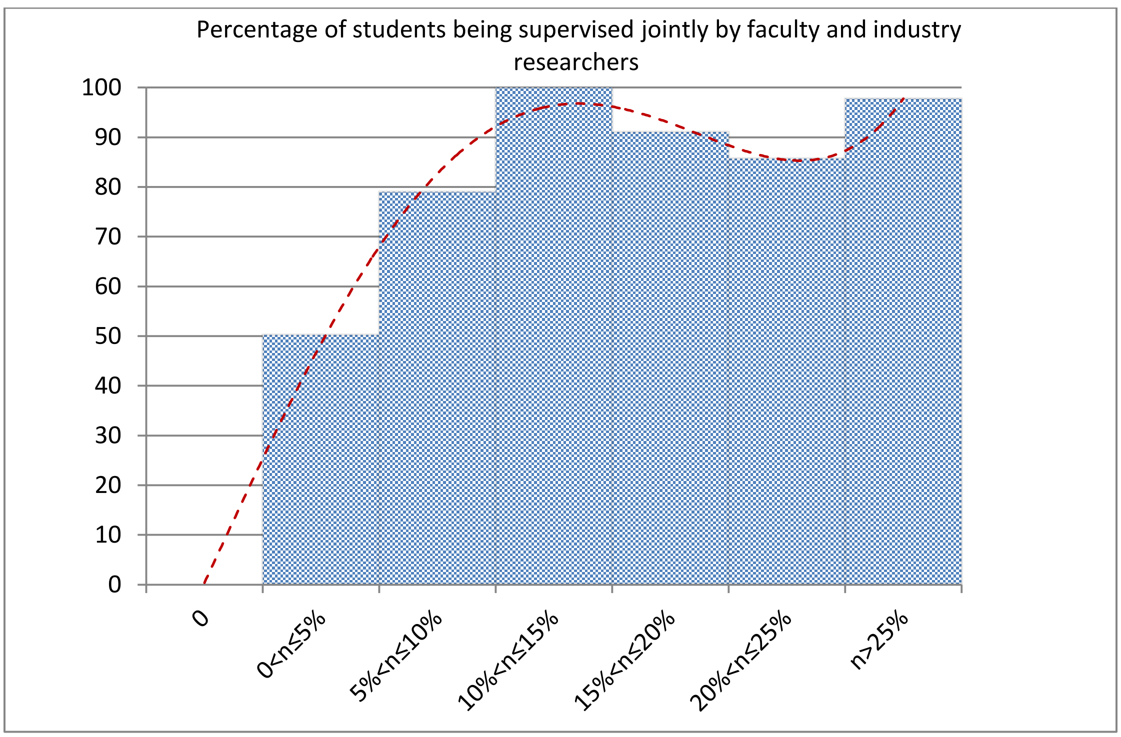
APPENDIX I -13: DESIRABILITY CURVE OF “NUMBER OF FACULTY MEMBERS CONDUCTING SHORT TRAINING COURSES” METRIC

	Percentage of faculty conducting short training courses for industry					
Expert	*0*	*0<n≤20%*	*20%<n≤40%*	*40%<n≤60%*	*60%<n≤80%*	*80%<n≤100%*
AR5	0	30	45	39	33	5
AR10	0	40	60	50	40	10
AR18	0	80	100	50	30	0
TM7	0	42	30	21	15	8
AR21	0	7	9	12	18	31
AR1	0	80	95	60	20	5
AR4	0	30	43	30	2	0
Mean	0	47	56	37	21	9
Normalized	0	83	100	66	37	16



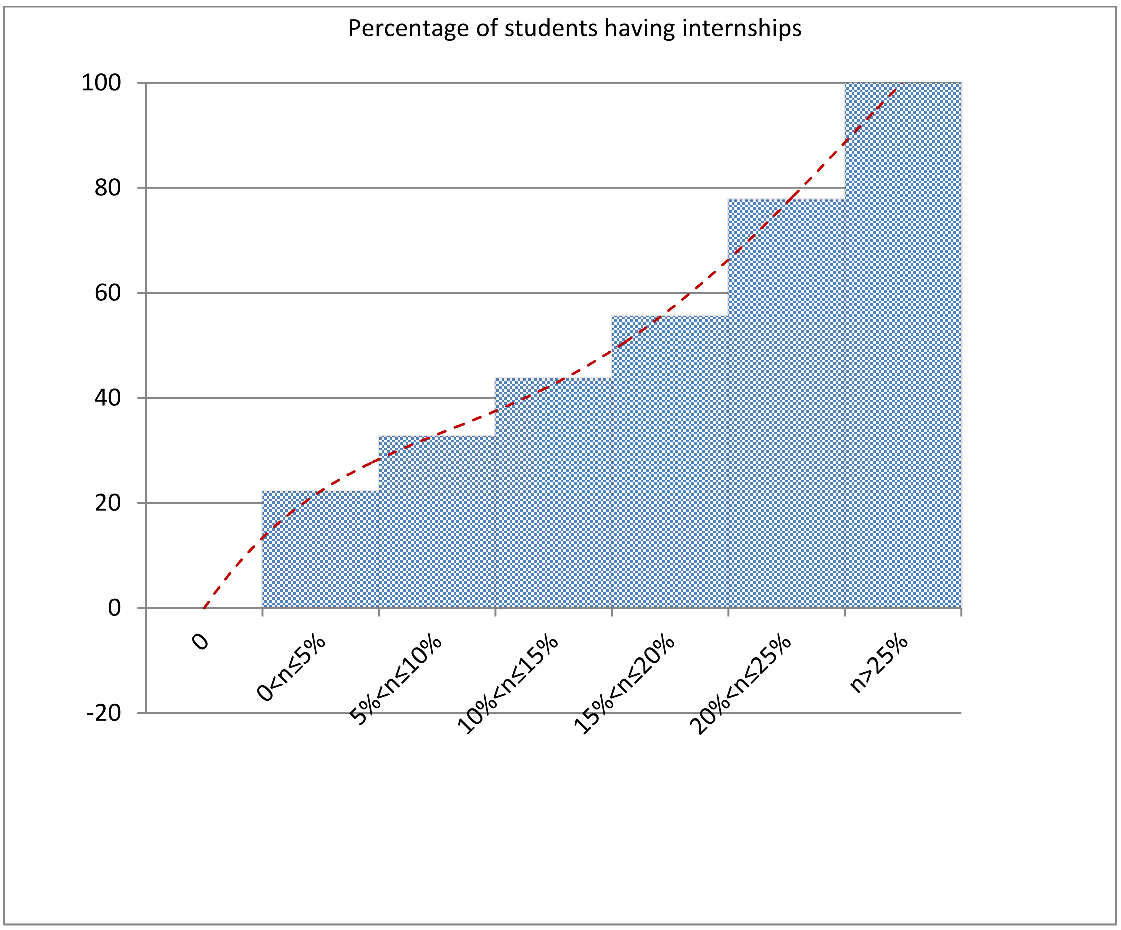
APPENDIX I -14: DESIRABILITY CURVE OF "NUMBER OF STUDENTS JOINTLY SUPERVISED BY FACULTY AND INDUSTRY MEMBERS" METRIC

	Percentage of students being supervised jointly by faculty and industry researchers						
Expert	*0*	*0<n≤5%*	*5%<n≤10%*	*10%<n≤15%*	*15%<n≤20%*	*20%<n≤25%*	*n>25%*
AR5	0	29	44	57	38	16	1
AR10	0	10	20	50	70	80	100
AR18	0	40	70	100	70	20	0
TM7	0	42	30	21	13	4	1
AR19	0	0	0	0	0	51	100
AR21	0	6	9	12	16	21	24
AR1	0	45	90	85	70	50	40
AR4	0	8	20	33	49	65	84
Mean	0	23	35	45	41	38	44
Normalized	0	50	79	100	91	86	98



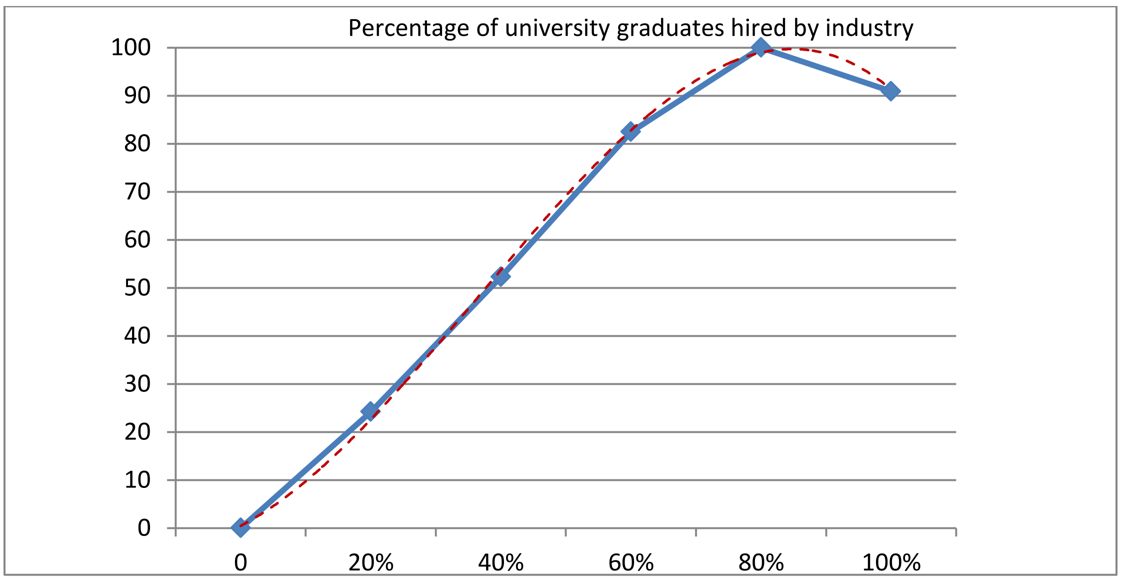
APPENDIX I -15: DESIRABILITY CURVE OF "NUMBER OF STUDENTS HAVING INTERNSHIPS IN INDUSTRY" METRIC

	Percentage of students having internships						
Expert	*0*	*0<n≤5%*	*5%<n≤10%*	*10%<n≤15%*	*15%<n≤20%*	*20%<n≤25%*	*n>25%*
AR10	0	10	20	40	60	80	100
AR19	0	0	0	0	0	50	100
AR21	0	15	20	25	30	34	39
AR1	0	70	80	85	90	95	95
AR4	0	0	20	37	58	74	94
Mean	0	19	28	37	48	67	86
Normalized	0	22	33	44	56	78	100



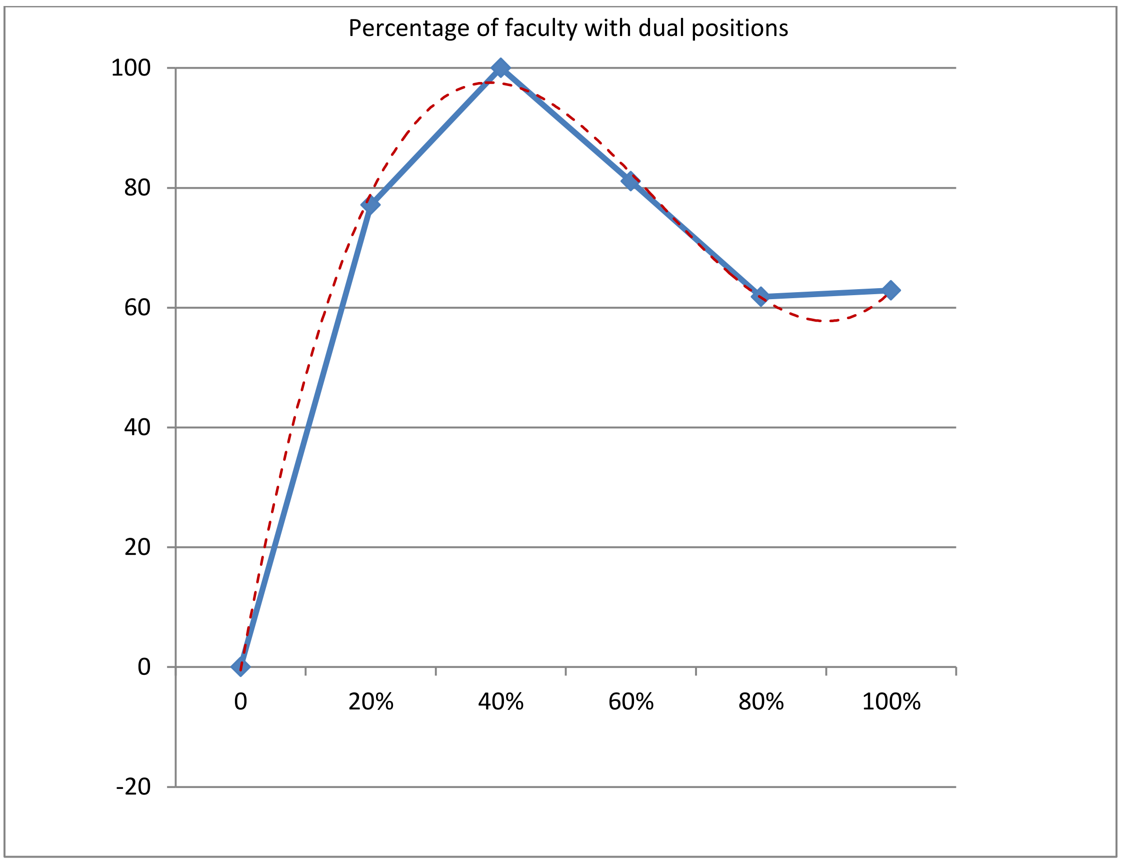
APPENDIX I -16: DESIRABILITY CURVE OF "NUMBER OF GRADUATES HIRED BY INDUSTRY" METRIC

	Percentage of university graduates hired					
Expert	*0*	*20%*	*40%*	*60%*	*80%*	*100%*
AR10	0	10	20	50	80	100
AR19	0	0	10	30	50	80
AR21	0	20	25	30	34	39
AR1	0	25	70	90	75	5
AR4	0	14	24	35	46	35
Mean	0	14	30	47	57	52
Normalized	0	24	52	82	100	91



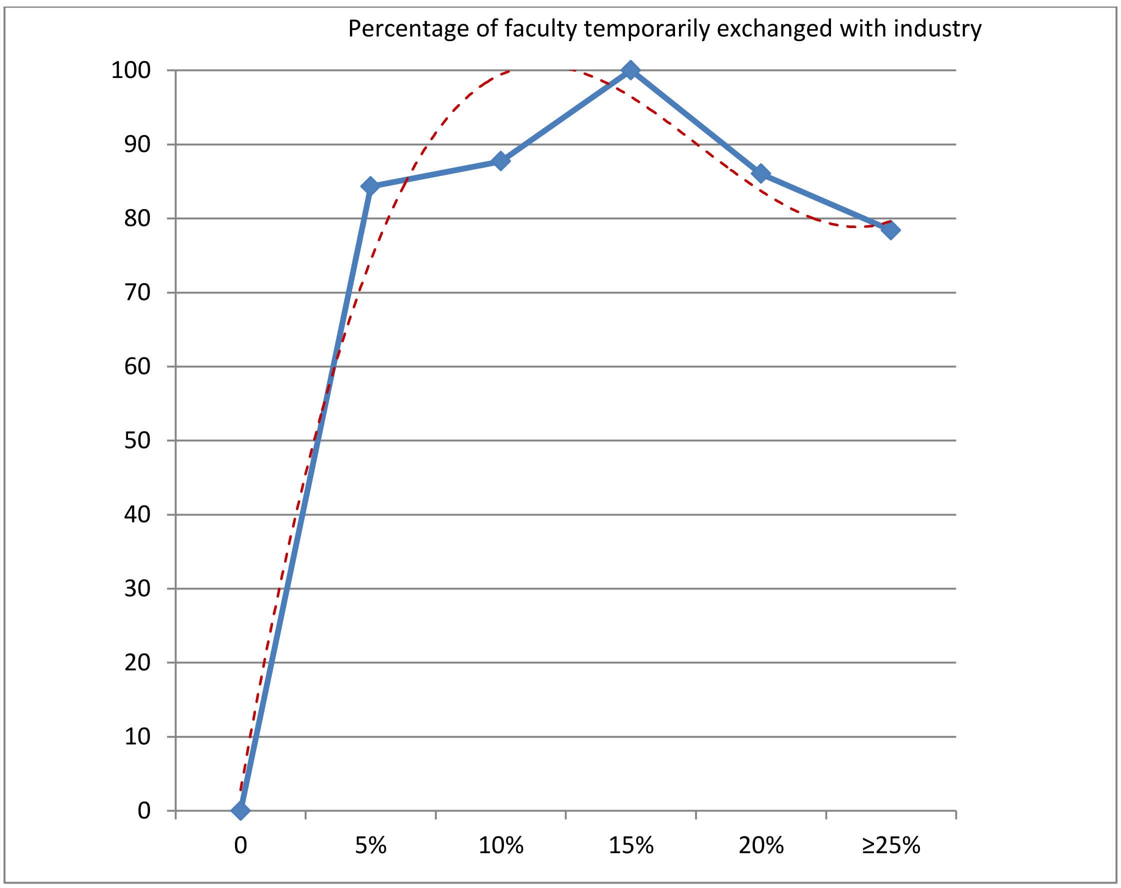
APPENDIX I -17: DESIRABILITY CURVE OF "NUMBER OF FACULTY WITH DUAL POSITIONS" METRIC

	Percentage of faculty with dual positions					
Expert	*0*	*20%*	*40%*	*60%*	*80%*	*100%*
AR10	0	40	60	70	60	50
AR19	0	50	100	50	5	5
AR21	0	20	25	30	34	39
AR1	0	75	50	20	8	5
AR4	0	31	45	57	66	77
Mean	0	43	56	45	35	35
Normalized	0	77	100	81	62	63



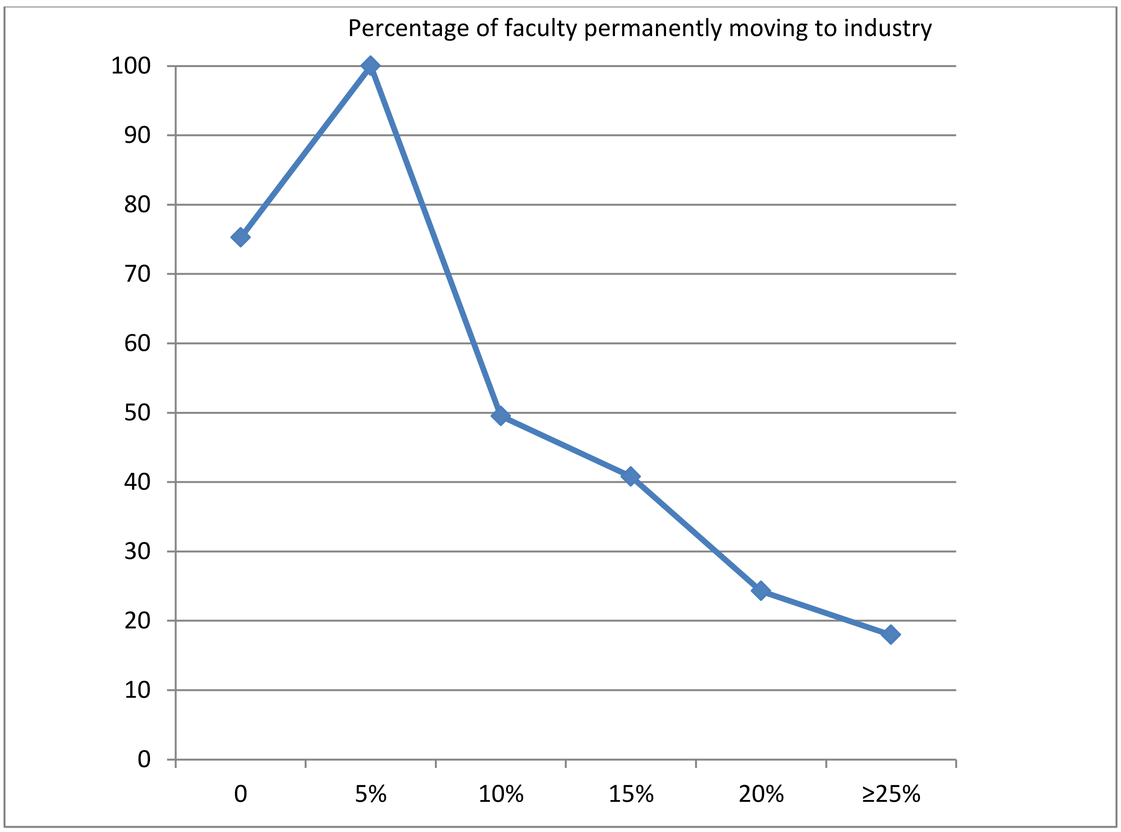
APPENDIX I -18: DESIRABILITY CURVE OF "NUMBER OF FACULTY TEMPORARILY EXCHANGED WITH INDUSTRY" METRIC

	Percentage of faculty temporarily exchanged with industry					
Expert	*0*	*5%*	*10%*	*15%*	*20%*	*≥25%*
AR10	0	20	40	70	80	100
AR19	0	50	100	100	50	15
AR21	0	14	19	24	28	32
AR1	0	100	20	5	2	1
AR4	0	15	28	37	43	37
Mean	0	40	41	47	41	37
Normalized	0	84	88	100	86	78



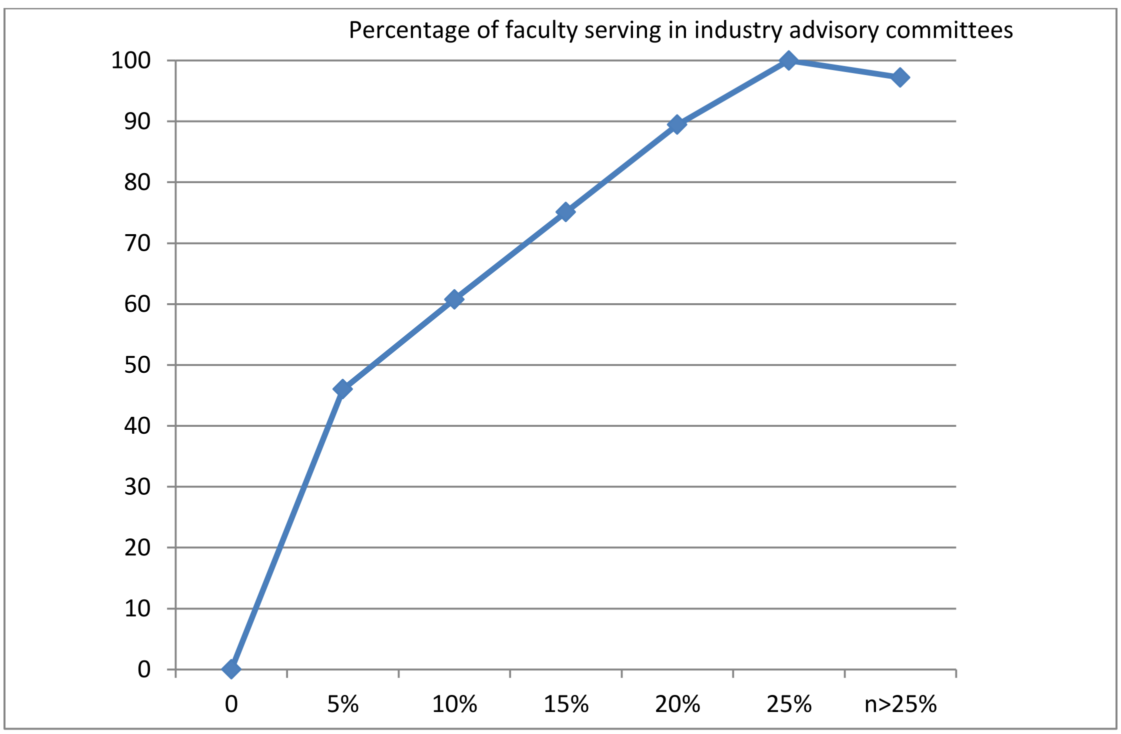
APPENDIX I -19: DESIRABILITY CURVE OF "NUMBER OF FACULTY PERMANENTLY MOVING TO INDUSTRY" METRIC

	Percentage of faculty permanently moving to industry					
Expert	*0*	*5%*	*10%*	*15%*	*20%*	*≥25%*
AR10	0	30	40	50	20	10
AR19	80	50	20	0	0	0
AR21	0	11	12	10	9	12
AR1	50	90	5	0	0	0
AR4	25	25	25	24	21	15
Mean	31	41	20	17	10	7
Normalized	75	100	50	41	24	18



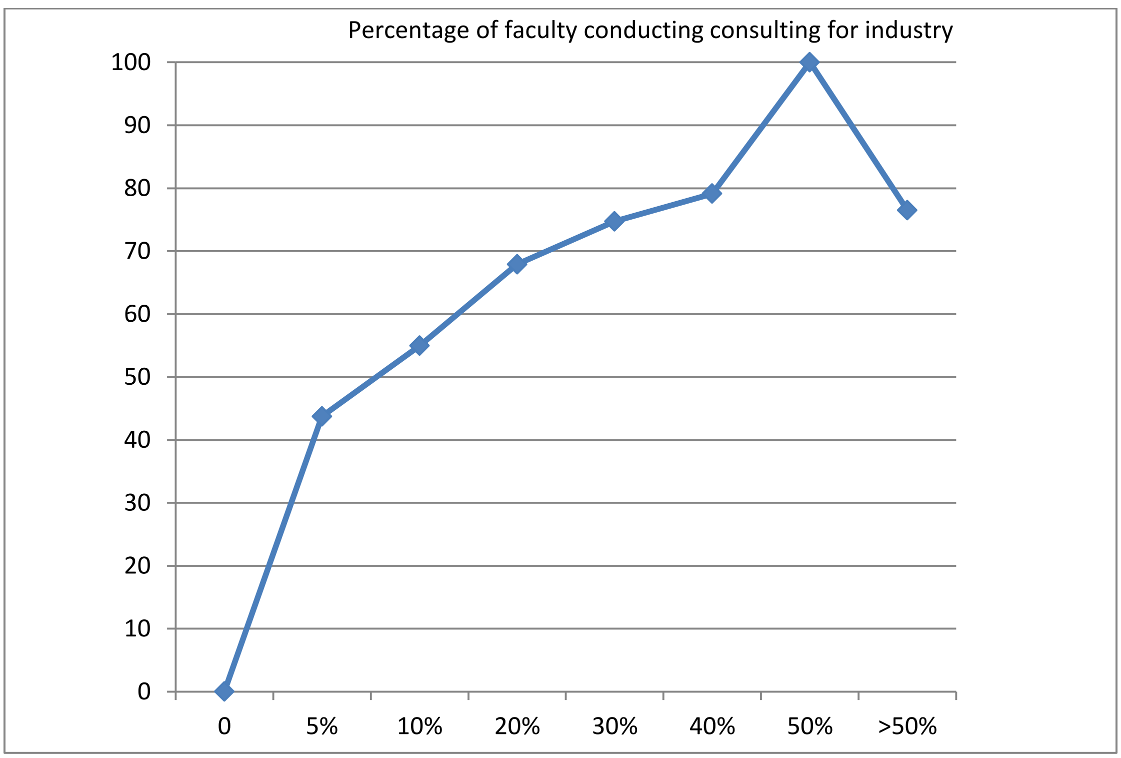
APPENDIX I -20: DESIRABILITY CURVE OF "NUMBER OF FACULTY SERVING IN INDUSTRY ADVISORY COMMITTEES" METRIC

	Percentage of faculty serving in industry advisory committees						
Expert	*0*	*5%*	*10%*	*15%*	*20%*	*25%*	*n>25%*
AR10	0	10	20	40	60	80	100
AR18	0	20	50	70	90	100	50
TM7	0	61	54	43	31	22	9
AR11	0	10	30	50	70	80	90
AR16	0	42	43	48	56	60	63
AR21	0	13	14	16	17	20	21
AR17	0	25	35	40	45	50	55
AR4	0	50	59	70	80	90	100
Mean	0	29	38	47	56	63	61
Normalized	0	46	61	75	89	100	97



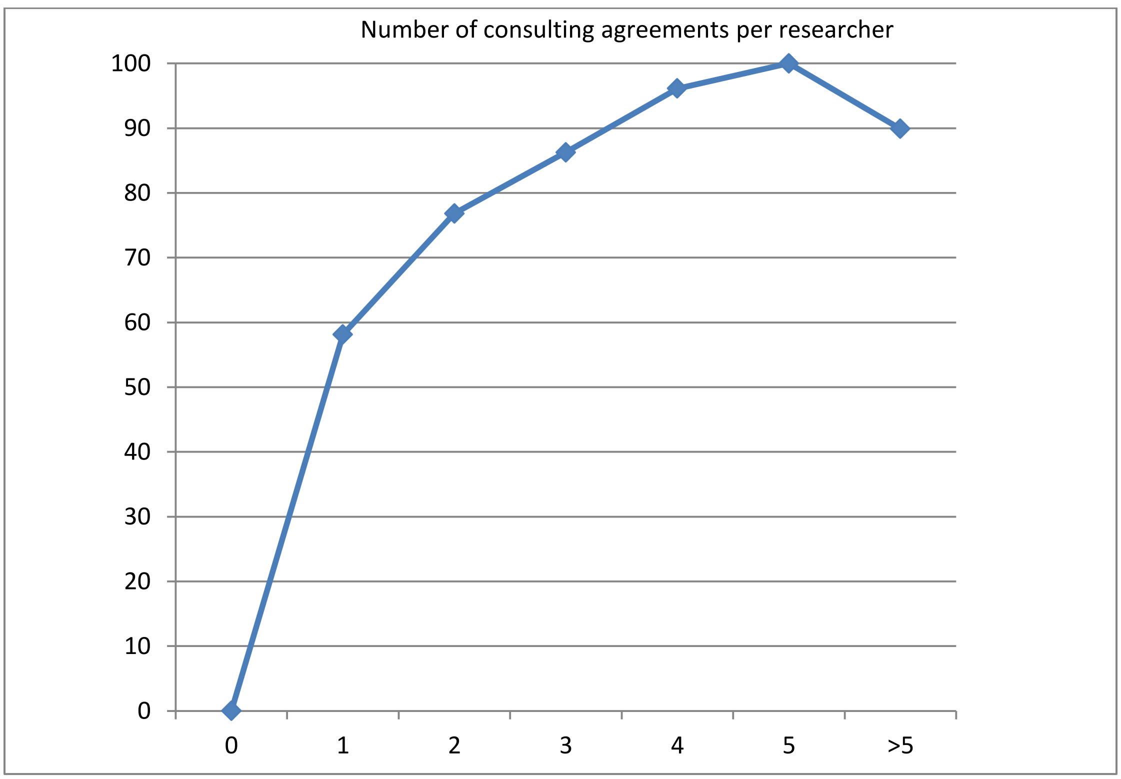
APPENDIX I -21: DESIRABILITY CURVE OF "NUMBER OF FACULTY CONDUCTING CONSULTING FOR INDUSTRY" METRIC

	Percentage of faculty conducting consulting for industry							
Expert	*0*	*5%*	*10%*	*20%*	*30%*	*40%*	*50%*	>50 %
AR10	0	10	20	30	40	60	80	90
AR18	0	30	50	70	80	90	100	0
TM7	0	51	40	31	20	10	50	2
AR11	0	10	20	30	40	50	60	70
AR16	0	54	57	59	62	64	66	69
AR21	0	5	7	9	12	14	34	55
AR17	0	25	30	35	40	45	50	60
AR4	0	14	26	45	46	27	15	2
Mean	0	25	31	39	43	45	57	44
Normalized	0	44	55	68	75	79	100	76



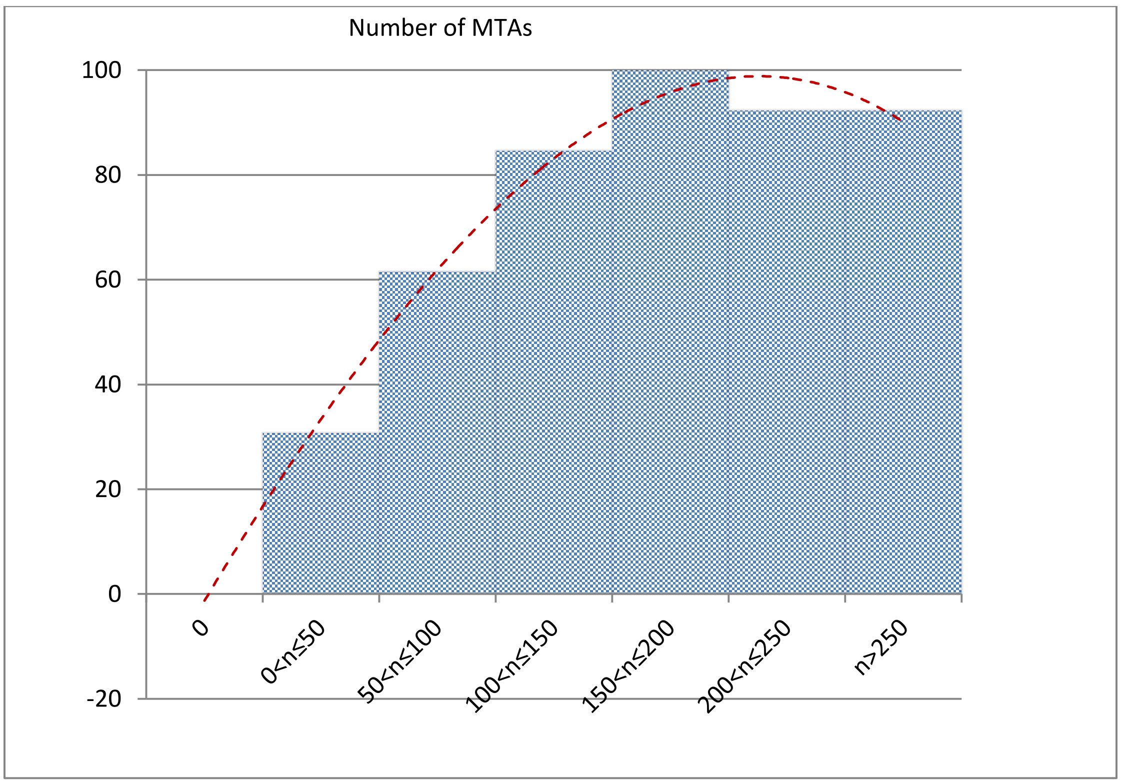
APPENDIX I -22: DESIRABILITY CURVE OF "NUMBER OF CONSULTING AGREEMENTS PER FACULTY MEMBER" METRIC

	Number of consulting agreements per researcher						
Expert	*0*	*1*	*2*	*3*	*4*	*5*	*>5*
AR10	0	10	10	20	40	50	60
AR18	0	20	50	70	90	100	30
TM7	0	50	59	70	78	83	94
AR11	0	30	60	47	32	20	10
AR16	0	52	53	58	58	57	58
AR21	0	21	32	34	36	37	42
AR17	0	70	60	50	40	30	25
AR4	0	18	34	53	74	89	100
Mean	0	34	45	50	56	58	52
Normalized	0	58	77	86	96	100	90



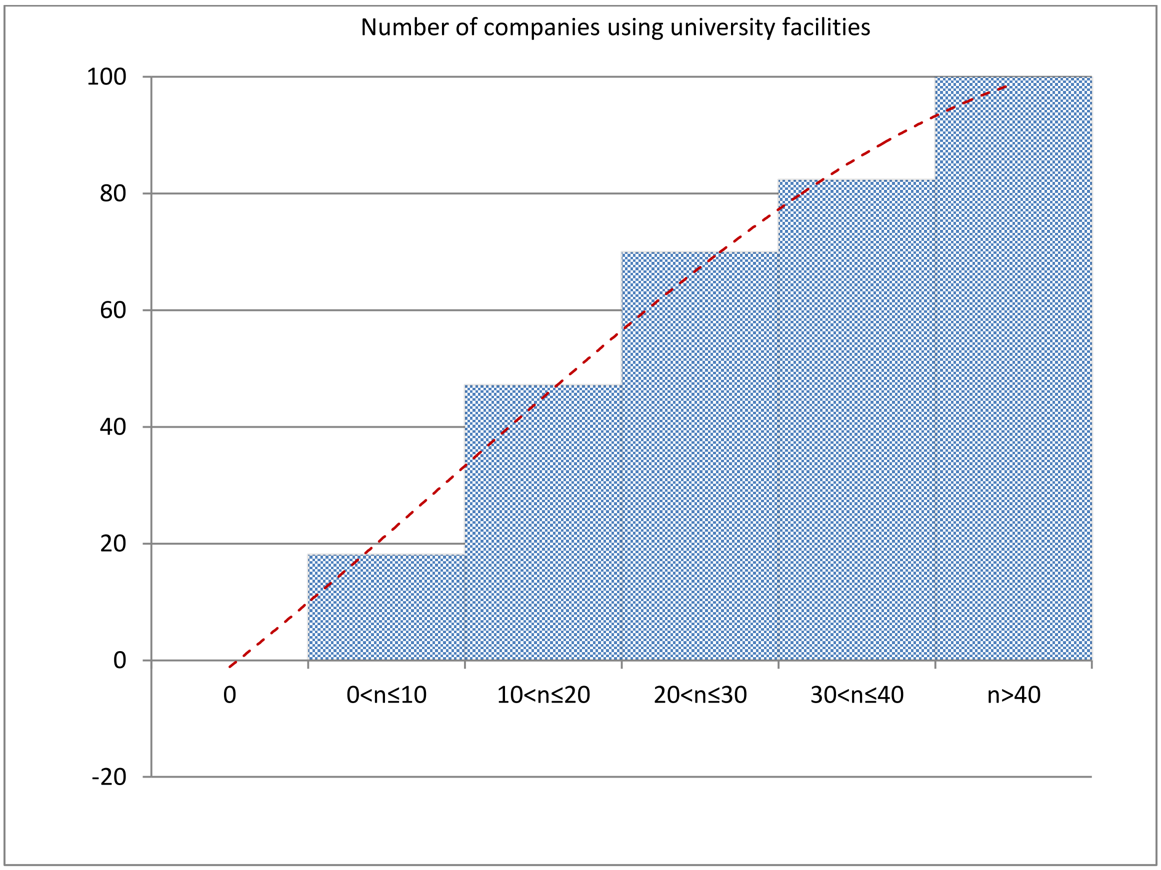
APPENDIX I -23: DESIRABILITY CURVE OF “NUMBER OF MTAs” METRIC

	Number of MTAs						
Expert	*0*	*0<n≤5*0	*50<n≤10*0	*100<n≤15*0	*150<n≤20*0	*200<n≤25*0	*n>250*
AR10	0	10	30	40	50	60	80
AR11	0	0	20	40	50	30	10
AR4	0	30	30	30	30	30	30
Mean	0	13	27	37	43	40	40
Normalized	0	31	62	85	100	92	92



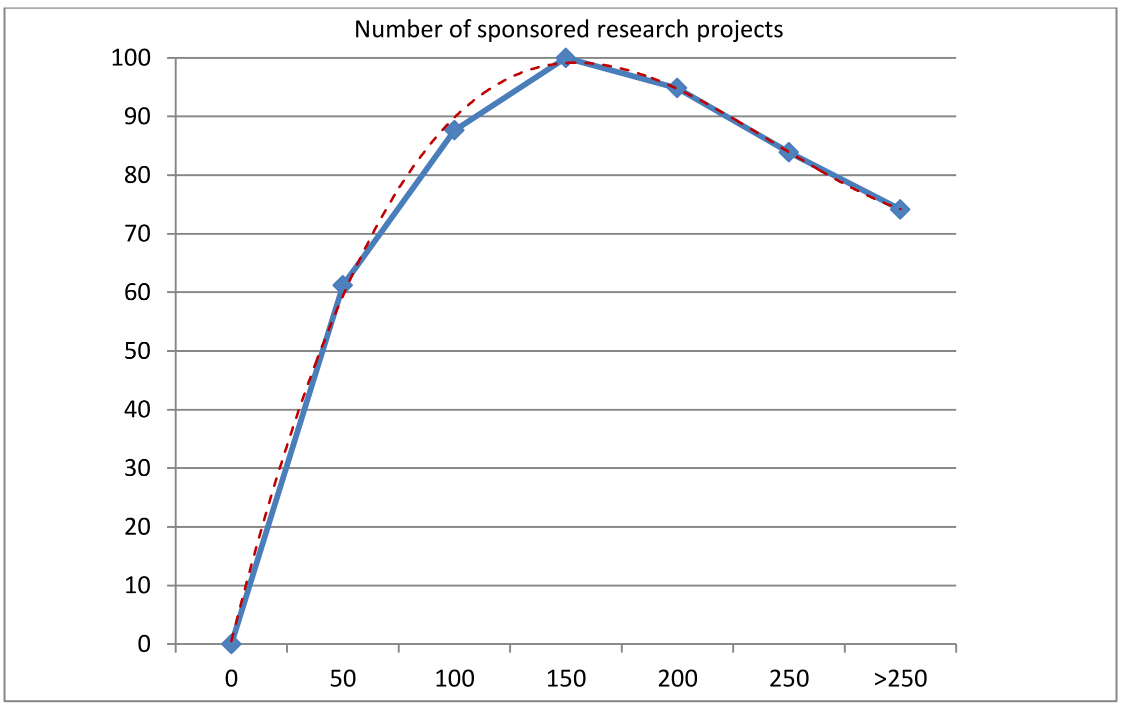
APPENDIX I -24: DESIRABILITY CURVE OF “NUMBER OF COMPANIES USING UNIVERSITY FACILITIES” METRIC

Expert	Number of companies using university facilities					
	0	*0<n*≤10	*10<n*≤20	*20<n*≤30	*30<n*≤40	*n>40*
AR10	0	0	30	50	70	100
AR11	0	15	25	35	23	12
AR4	0	20	36	50	66	81
Mean	0	12	30	45	53	64
Normalized	0	18	47	70	82	100



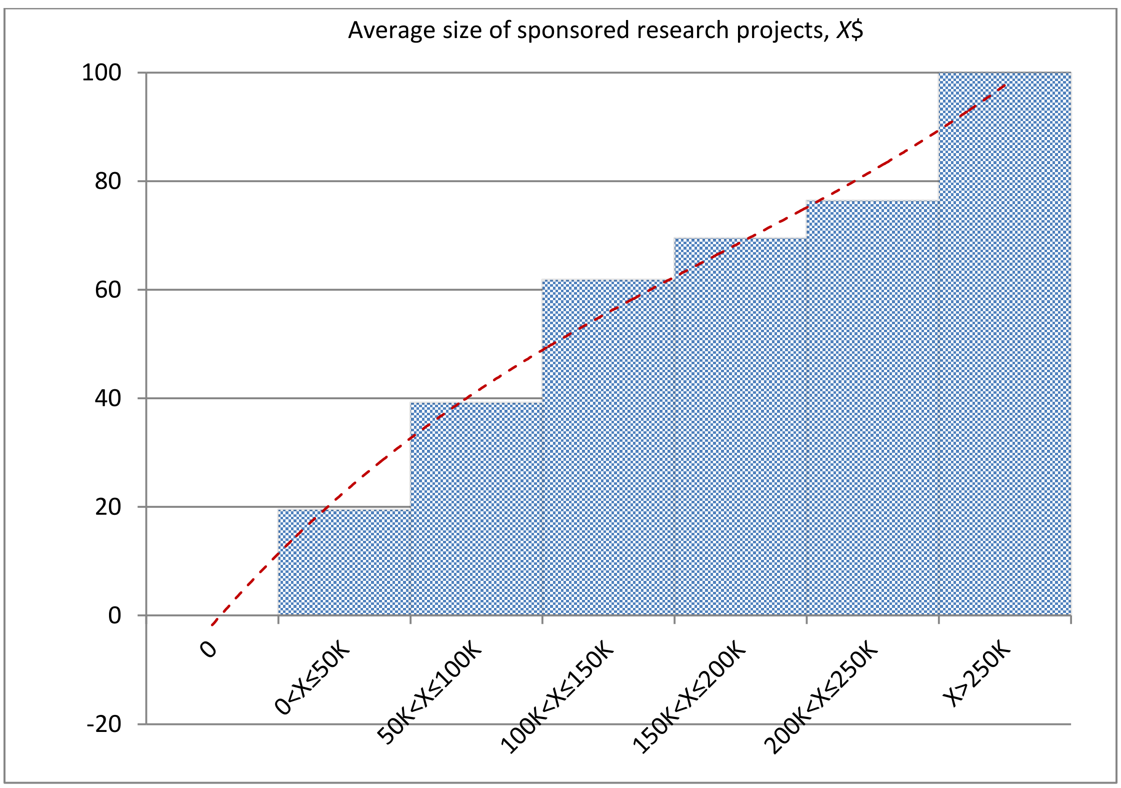
APPENDIX I -25: DESIRABILITY CURVE OF "NUMBER OF INDUSTRY SPONSORED RESEARCH PROJECTS" METRIC

	Number of sponsored research projects						
Expert	*0*	*50*	*100*	*150*	*200*	*250*	*>250*
AR10	0	20	40	50	60	80	100
AR18	0	50	70	90	100	50	10
AR6	0	10	50	50	46	42	37
AR11	0	10	20	30	40	30	20
AR19	0	50	50	50	9	9	5
AR17	0	60	50	40	30	25	20
AR4	0	13	25	38	45	56	66
Mean	0	30	44	50	47	42	37
Normalized	0	61	88	100	95	84	74



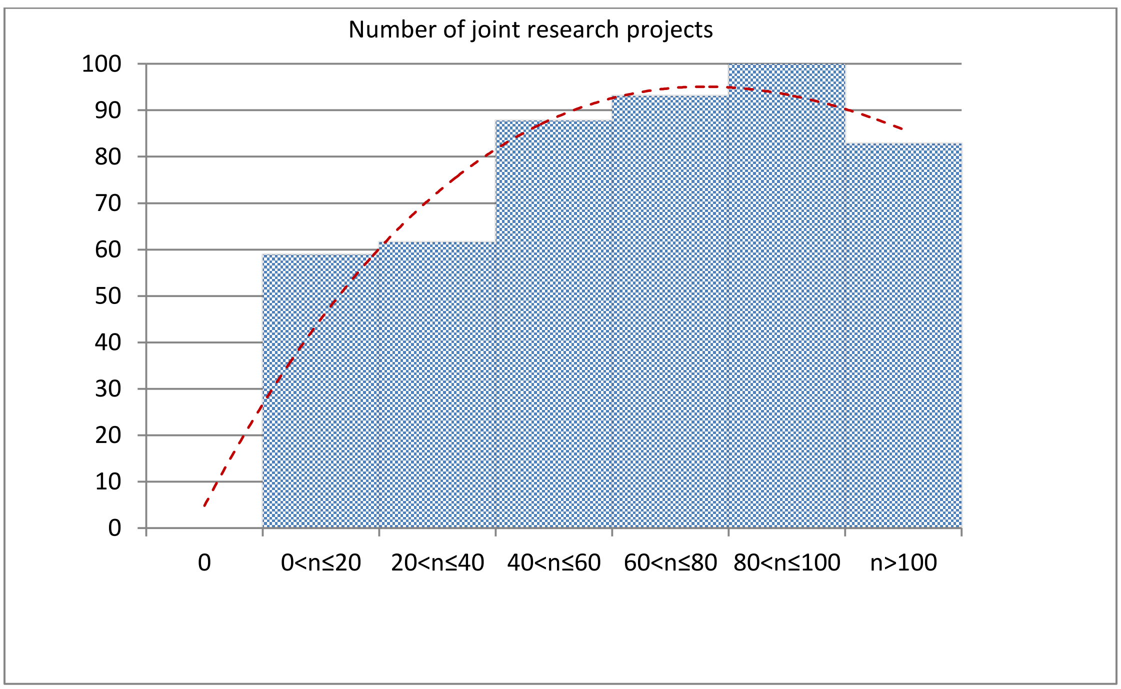
APPENDIX I -26: DESIRABILITY CURVE OF "AVERAGE SIZE OF INDUSTRY SPONSORED RESEARCH PROJECTS" METRIC

	Average size of sponsored research projects, $						
Expert	*0*	*0<X≤*50K	*50K<X≤*100K	*100K<X≤*150K	*150K<X≤*200K	*200K<X≤*250K	*X>250K*
AR10	0	10	40	60	70	80	100
AR18	0	30	50	70	73	75	100
TM7	0	20	30	40	45	50	70
AR6	0	10	20	30	35	37	80
AR11	0	10	40	60	70	80	100
AR19	0	5	10	60	60	60	60
AR17	0	30	40	50	60	70	70
AR1	0	15	31	42	50	57	86
AR4	0	16	33	52	58	64	83
Mean	0	20	39	62	70	76	100



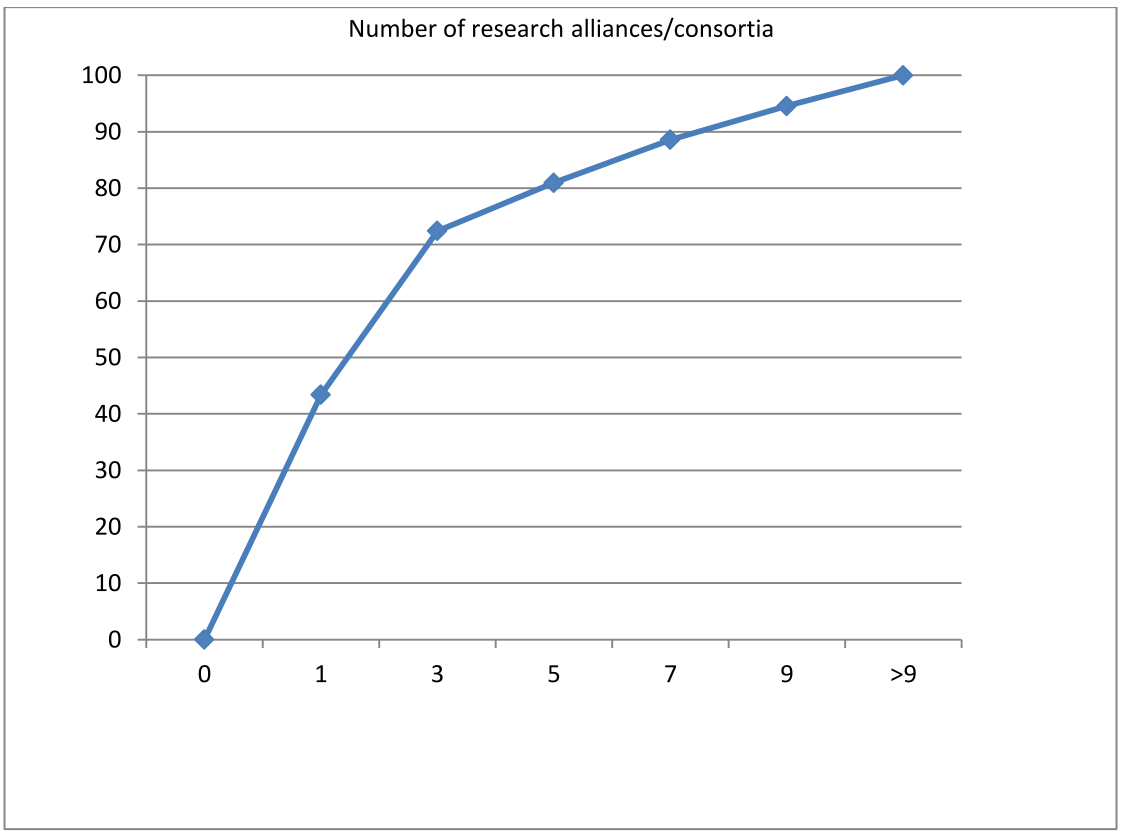
APPENDIX I -27: DESIRABILITY CURVE OF “NUMBER OF JOINT RESEARCH PROJECTS” METRIC

	Number of joint research projects						
Expert	*0*	*0<n≤20*	*20<n≤40*	*40<n≤60*	*60<n≤80*	*80<n≤100*	*n>100*
AR10	0	20	40	60	80	90	100
AR18	0	30	50	70	86	100	50
TM7	0	50	58	66	73	90	94
AR6	0	50	56	57	57	58	57
AR11	0	20	40	70	40	20	0
AR19	0	5	10	60	60	60	10
AR17	0	20	25	30	35	40	45
AR1	0	90	10	5	5	5	5
AR4	0	25	35	44	54	63	75
Mean	0	34	36	51	54	58	48
Normalized	0	59	62	88	93	100	83



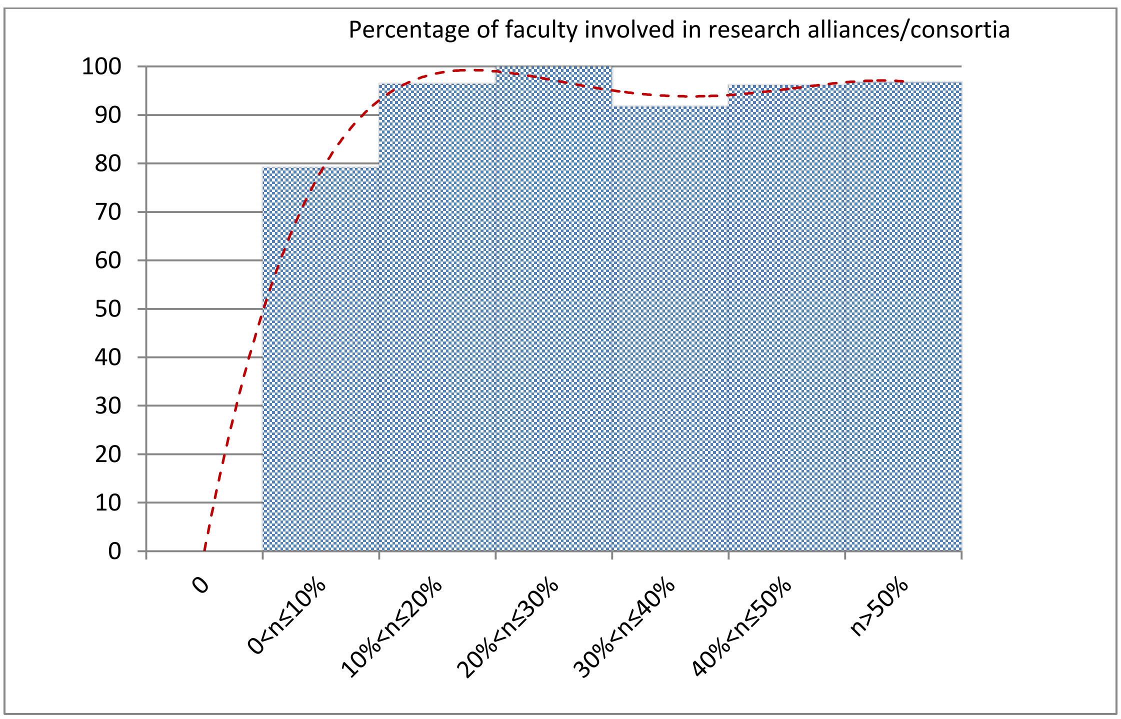
APPENDIX I -28: DESIRABILITY CURVE OF "NUMBER OF RESEARCH ALLIANCES" METRIC

	Number of research alliances/consortia						
Expert	*0*	*1*	*3*	*5*	*7*	*9*	*>9*
AR10	0	10	30	50	70	90	100
AR18	0	39	60	80	91	100	100
TM7	0	60	69	78	86	90	95
AR6	0	20	50	70	70	70	70
AR11	0	10	20	10	10	0	0
AR19	0	30	50	20	5	0	0
AR17	0	20	25	30	35	40	45
AR1	0	50	95	80	70	60	50
AR4	0	0	0	28	51	71	91
Mean	0	27	44	50	54	58	61
Normalized	0	43	72	81	89	95	100



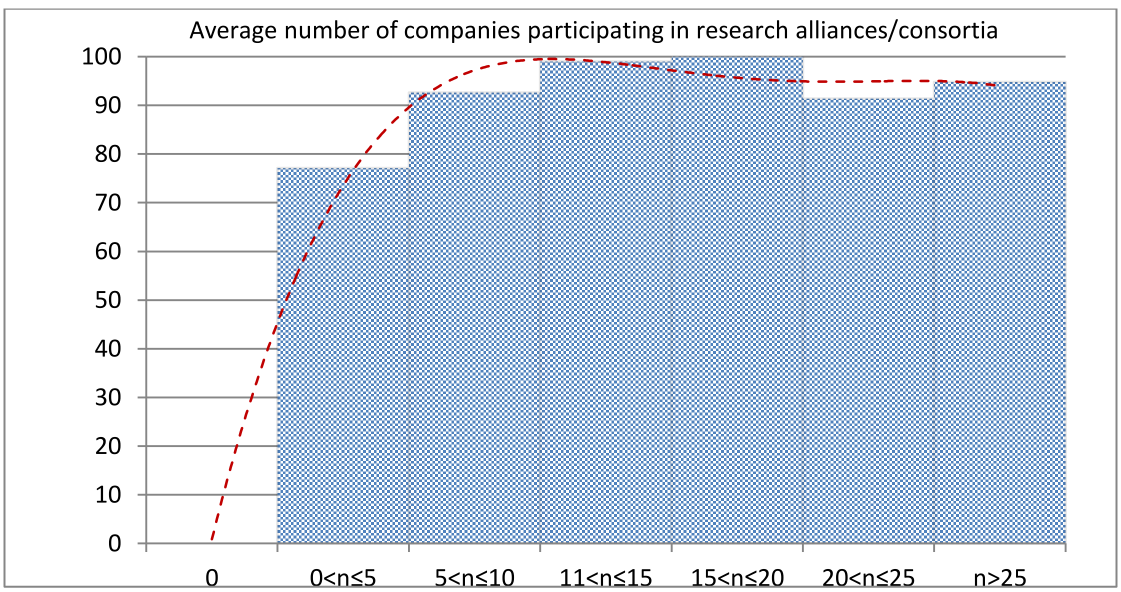
APPENDIX I -29: DESIRABILITY CURVE OF “NUMBER OF FACULTY MEMBERS INVOLVED IN RESEARCH ALLIANCES” METRIC

	Percentage of faculty involved in research alliances/consortia						
Expert	*0*	*0<n≤10* %	*10%<n≤20* %	*20%<n≤30* %	*30%<n≤40* %	*40%<n≤50* %	*n>5 0%*
AR10	0	10	30	40	60	90	100
AR18	0	10	20	40	50	80	100
TM7	0	24	29	35	45	54	63
AR6	0	60	70	70	70	70	70
AR11	0	20	10	0	0	0	0
AR19	0	20	40	60	60	50	30
AR17	0	20	25	30	35	40	45
AR1	0	90	90	40	20	10	10
AR4	0	26	45	66	33	24	12
Mean	0	34	41	43	39	41	41
Normalized	0	79	96	100	92	96	97



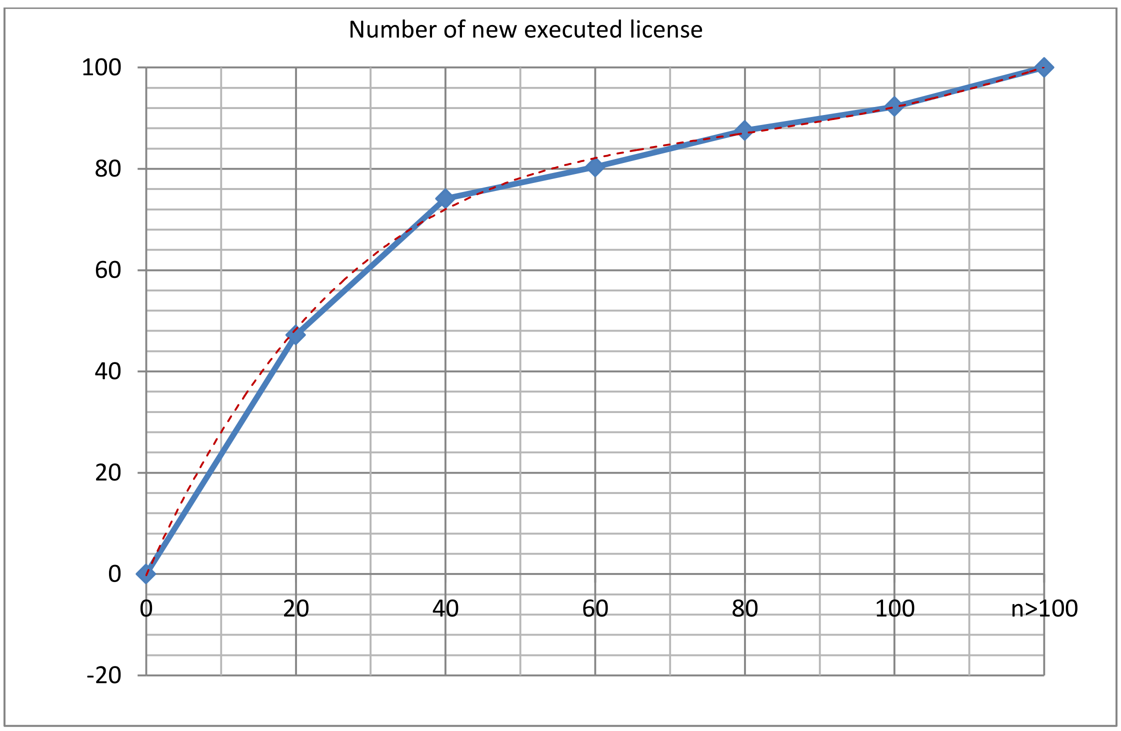
APPENDIX I -30: DESIRABILITY CURVE OF "AVERAGE NUMBER OF COMPANIES PARTICIPATING IN A RESEARCH ALLIANCE WITH THE UNVIERISTY" METRIC

	Average number of companies participating in research alliances/consortia						
Expert	*0*	*0<n≤* 5	*5<n≤*10	*11<n≤*15	*15<n≤*2 0	*20<n≤*2 5	*n>25*
AR10	0	100	70	40	20	10	0
AR18	0	10	20	40	54	60	100
TM7	0	34	39	46	52	60	67
AR6	0	40	60	60	60	60	60
AR11	0	10	10	5	2	0	0
AR19	0	20	50	50	30	10	5
AR17	0	20	25	30	35	40	46
AR1	0	80	95	100	100	100	100
AR4	0	0	8	32	54	32	8
Mean	0	35	42	45	45	41	43
Normalize d	0	77	93	99	100	91	95



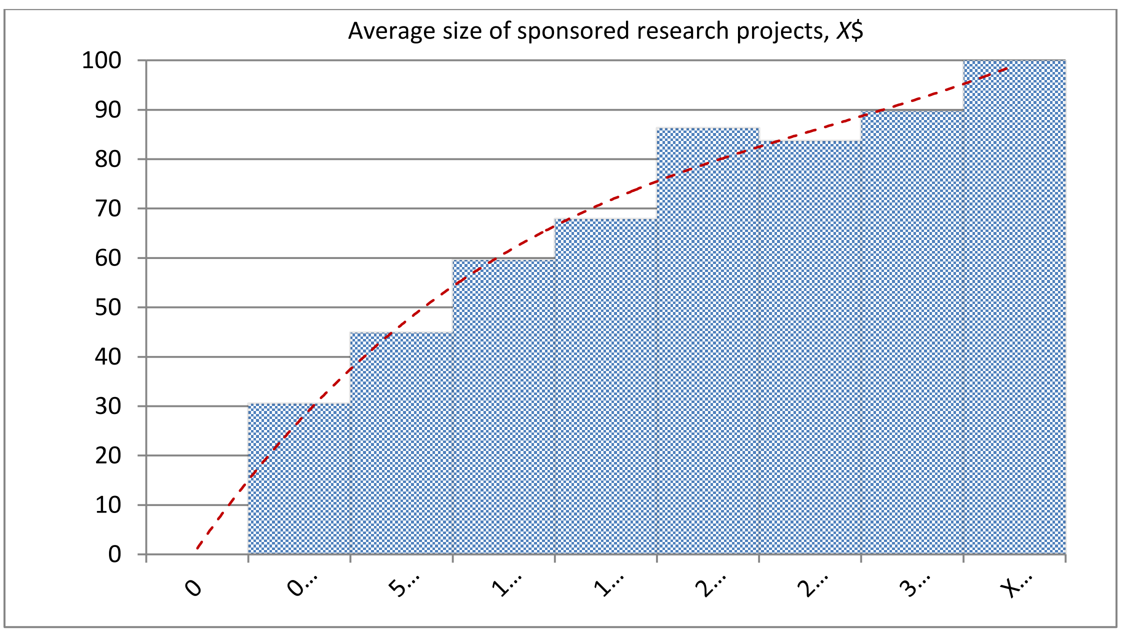
APPENDIX I -31: DESIRABILITY CURVE OF "NUMBER OF NEW EXECUTED LICENSES" METRIC

	Number of new executed licenses						
Expert	*0*	*20*	*40*	*60*	*80*	*100*	*n>100*
TM2	0	20	40	60	80	90	100
AR9	0	30	44	54	67	80	90
AR10	0	18	40	50	70	90	100
AR18	0	40	100	61	40	20	100
TM7	0	100	100	100	100	100	100
AR11	0	20	30	40	50	40	40
TM6	0	10	20	38	56	80	100
AR15	0	10	40	30	18	9	2
AR17	0	20	30	40	45	50	60
AR1	0	45	80	90	96	96	100
AR4	0	74	63	53	42	35	24
TM3	0	4	44	60	67	90	100
TM10	0	80	100	100	100	80	50
Mean	0	35	55	60	65	69	74
Normalized	0	47	74	80	88	92	100



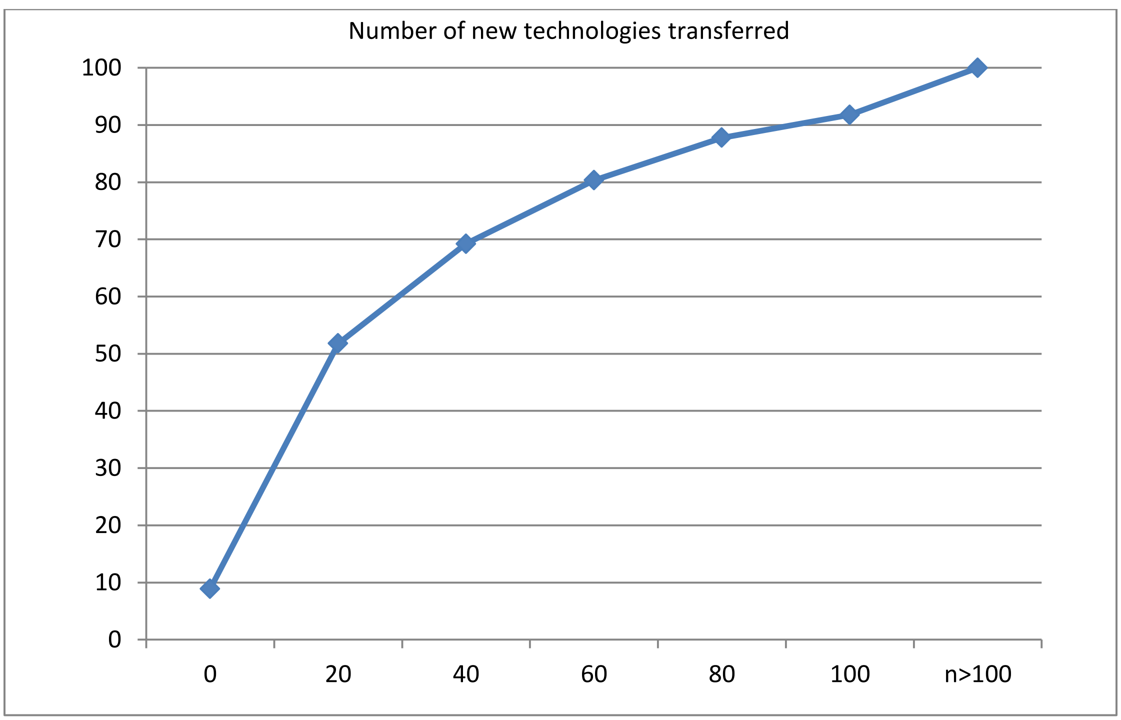
APPENDIX I -32: DESIRABILITY CURVE OF “AVERAGE INCOME OF NEW EXECUTED LICENSES” METRIC

	Average income of a new executed license, $								
Expert	*0*	*0<X≤50* K	*50K<X≤10* 0K	*100K<X≤15* 0K	*150K<X≤20* 0K	*200K<X≤25* 0K	*250K<X≤30* 0K	*300K<X≤* 350K	*X>350* *K*
TM2	0	10	20	30	45	60	75	90	100
AR9	0	29	42	54	6	78	87	93	100
AR10	0	6	10	19	30	40	60	80	100
AR18	0	10	20	30	35	40	45	50	100
TM7	0	30	36	44	56	63	74	83	91
AR11	0	20	40	60	70	78	64	53	44
TM6	0	20	40	60	80	100	100	100	100
AR15	0	9	25	50	77	100	2	2	2
AR17	0	20	30	40	45	50	55	65	70
AR1	0	50	70	75	80	85	90	95	100
AR4	0	96	95	95	95	95	95	95	95
TM3	0	5	21	39	60	74	90	91	98
Mean	0	25	37	50	57	72	70	75	83
Normalized	0	31	45	60	68	86	84	90	100



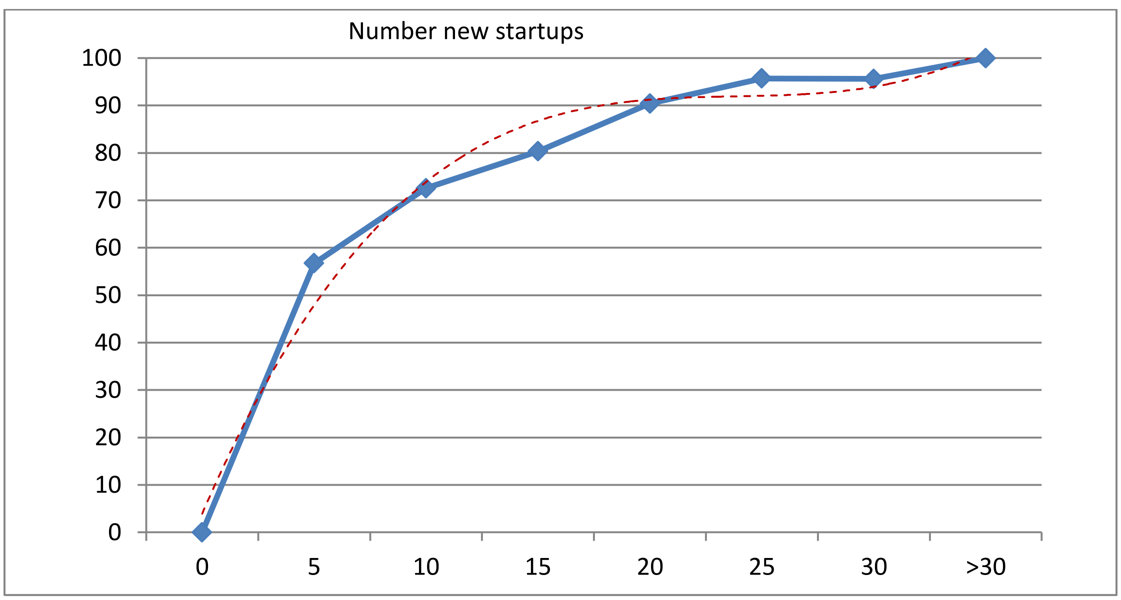
APPENDIX I -33: DESIRABILITY CURVE OF "NUMBER OF NEW TECHNOLOGIES TRANSFERRED" METRIC

	Number of technologies transferred						
Expert	*0*	*20*	*40*	*60*	*80*	*100*	*n>100*
TM2	0	20	40	60	80	90	100
AR9	0	60	70	80	90	97	100
AR10	0	10	30	40	50	70	80
AR18	0	40	60	80	90	95	100
TM7	80	30	37	50	58	66	80
AR11	0	10	18	26	34	44	52
TM6	0	10	20	40	60	81	100
AR15	0	70	60	55	45	7	1
AR17	0	25	35	40	45	50	60
AR1	0	50	90	95	98	99	100
AR4	0	71	63	51	31	18	6
TM3	0	0	0	6	9	29	71
TM10	0	70	100	100	100	80	50
Mean	6	36	48	56	61	64	69
Normalized	9	52	69	80	88	92	100



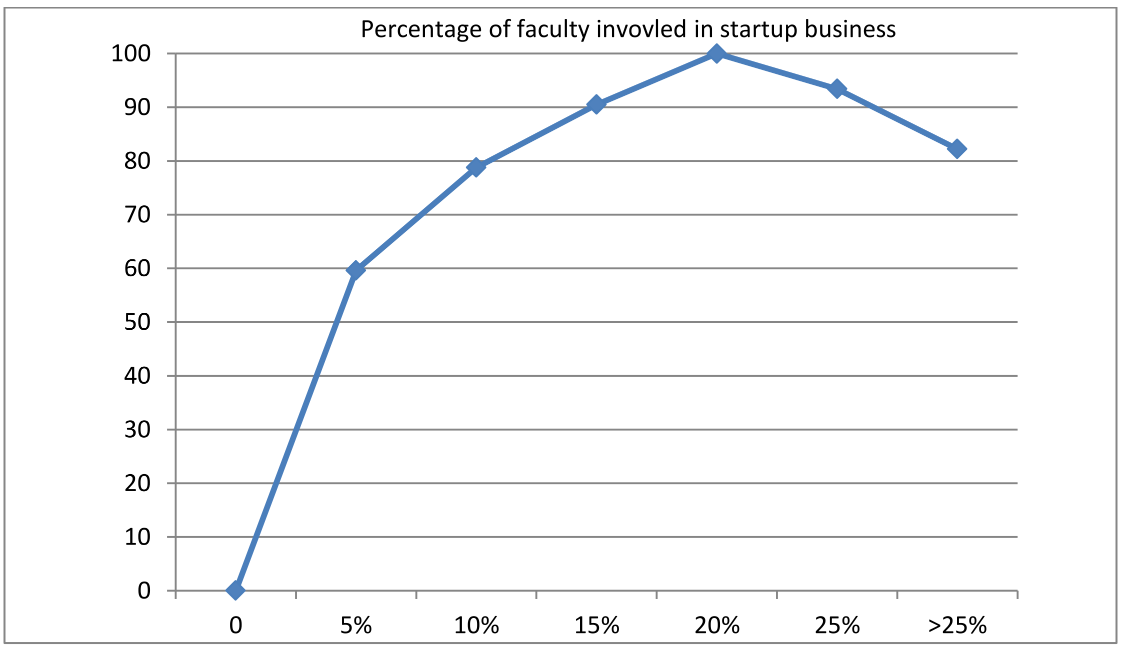
APPENDIX I -34: DESIRABILITY CURVE OF "NUMBER OF NEW STARTUPS" METRIC

	Number of new start-ups							
Expert	*0*	*5*	*10*	*15*	*20*	*25*	*30*	*>30*
AR9	0	28	45	57	68	77	87	96
AR10	0	4	10	60	80	100	90	80
AR18	0	10	30	50	70	86	98	100
TM7	0	50	60	66	75	83	90	97
AR11	0	20	35	45	55	67	80	100
AR16	0	41	42	45	49	50	52	53
AR19	0	80	46	22	9	3	2	1
AR21	0	8	15	22	37	52	65	80
AR8	0	50	60	71	82	88	95	100
AR17	0	20	25	30	35	40	45	55
AR1	0	50	100	70	60	60	60	60
AR4	0	50	60	70	80	50	30	10
TM3	0	30	80	80	80	80	66	66
TM10	0	100	80	70	70	60	30	0
Mean	0	36	47	52	58	61	61	64
Normalized	0	57	73	80	90	96	96	100



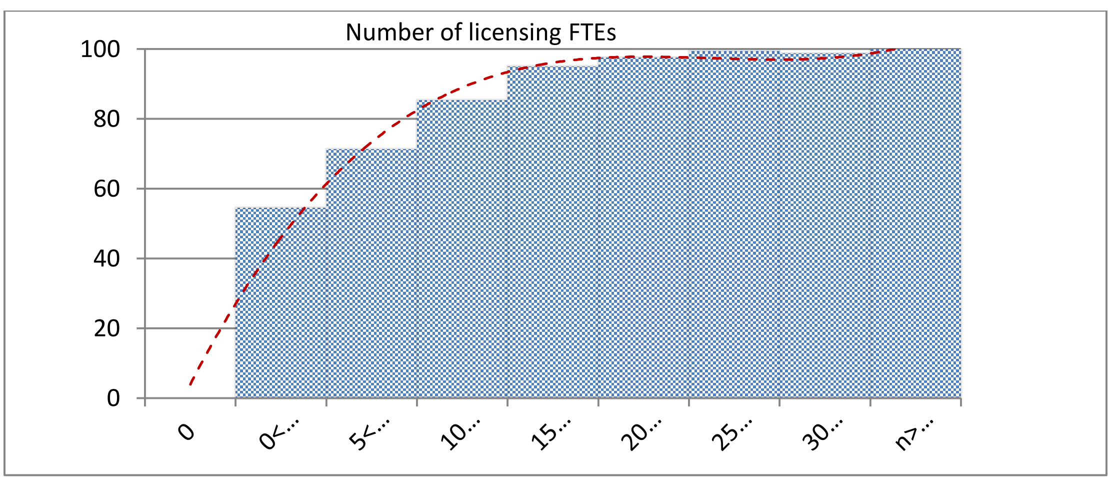
APPENDIX I -35: DESIRABILITY CURVE OF "NUMBER OF FACULTY MEMBERS INVOLVED IN STARTUP BUSINESS" METRIC

	Percentage of faculty invovled in startup business						
Expert	*0*	*5%*	*10%*	*15%*	*20%*	*25%*	*>25%*
AR9	0	23	39	55	70	85	74
AR10	0	10	30	50	80	100	90
AR18	0	50	70	90	100	70	20
TM7	0	60	54	46	34	26	10
AR11	0	28	50	73	100	70	50
AR16	0	32	34	38	39	10	43
AR19	0	25	47	68	69	55	37
AR21	0	11	13	14	15	17	21
AR8	0	50	58	59	59	57	56
AR17	0	20	25	30	35	40	45
AR1	0	90	100	100	100	100	95
AR4	0	31	42	52	64	72	84
TM3	0	40	91	90	91	91	61
TM10	0	100	100	100	100	100	100
Mean	0	41	54	62	68	64	56
Normalized	0	60	79	90	100	93	82



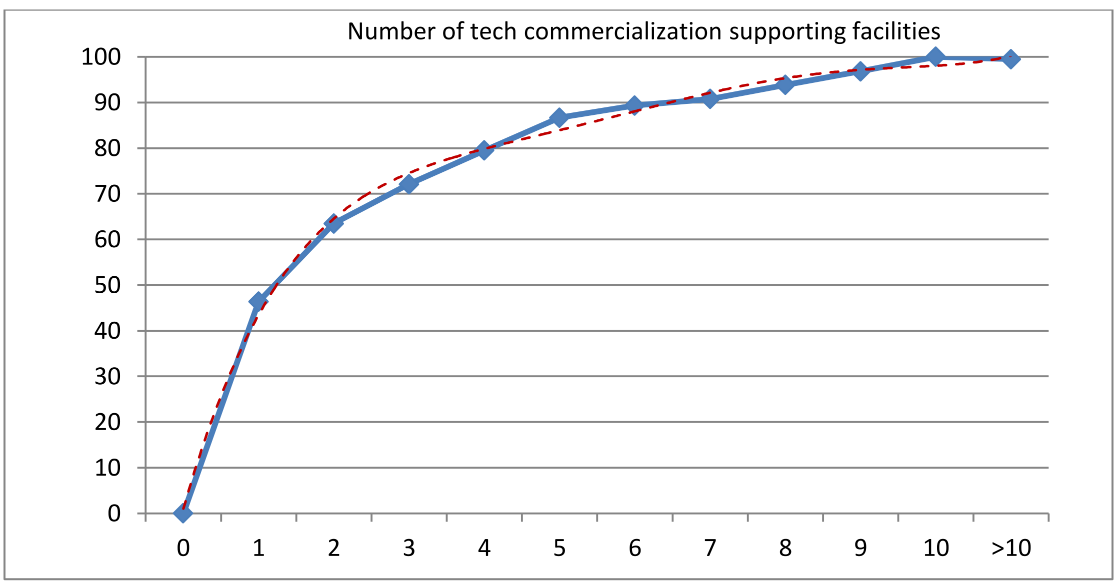
APPENDIX I -36: DESIRABILITY CURVE OF "NUMBER OF LICENSING FTES" METRIC

	Number licensing FTEs								
Expert	*0*	*0<n≤5*	*5<n≤10*	*10<n≤15*	*15<n≤20*	*20<n≤25*	*25<n≤30*	*30<n≤35*	*n>35*
AR5	0	35	44	40	32	10	0	0	0
TM2	0	15	30	45	60	75	90	100	100
AR9	0	23	33	44	55	66	76	87	96
AR10	0	10	30	50	60	62	67	70	80
AR18	0	50	70	90	100	80	50	30	5
AR6	0	10	20	30	35	40	45	45	45
AR11	0	10	18	23	35	40	45	45	45
AR16	0	47	50	52	54	55	56	57	57
TM6	0	20	37	54	71	91	100	100	100
AR21	0	20	13	23	29	33	37	43	64
AR8	0	40	60	70	80	82	83	83	70
AR15	0	91	78	47	30	12	5	1	1
AR17	0	20	75	100	100	100	100	100	100
AR1	0	30	29	30	35	45	50	55	60
AR4	0	26	50	70	80	90	94	97	100
TM10	0	60	26	25	26	25	25	4	5
Mean	0	32	41	50	55	57	58	57	58
Normalized	0	55	71	85	95	98	99	99	100



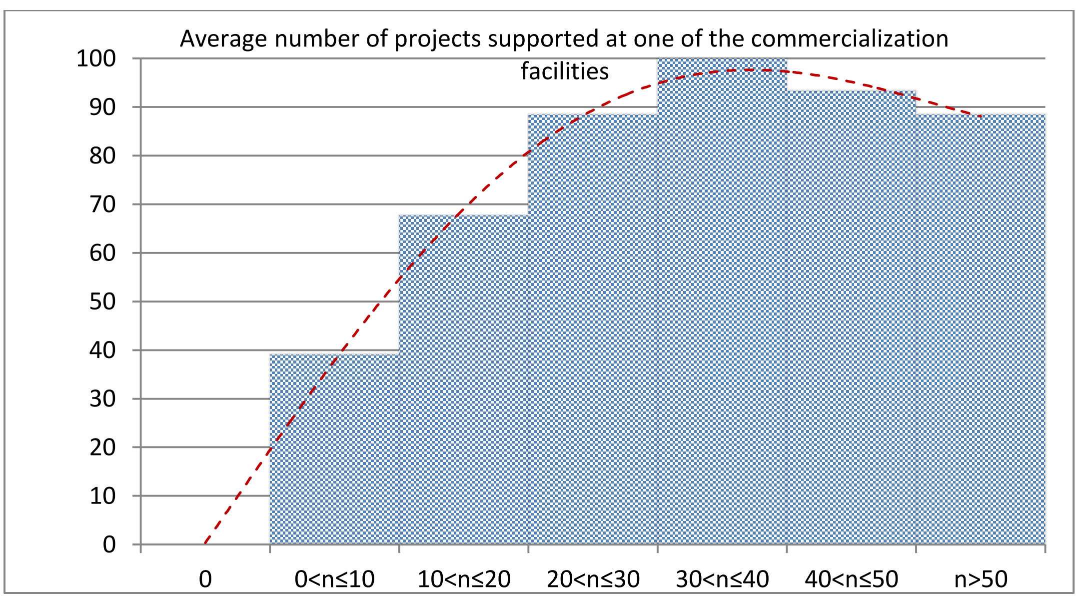
APPENDIX I -37: DESIRABILITY CURVE OF "NUMBER OF TECHNOLOGY COMMERCIALIZATION SUPPORT FACILITIES" METRIC

	Number of tech commercialization supporting facilities											
Expert	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*>10*
AR5	0	29	48	41	38	36	1	0	0	0	0	0
TM2	0	10	20	30	40	50	60	70	80	90	100	100
AR9	0	15	20	25	30	38	46	55	66	75	85	95
AR10	0	0	11	16	20	30	40	50	60	70	90	100
AR18	0	40	60	80	97	100	95	63	44	32	15	0
AR6	0	50	50	50	50	50	50	50	50	50	50	50
AR11	0	10	15	23	28	34	38	29	22	18	17	16
AR16	0	46	47	50	50	53	55	56	59	58	60	61
TM6	0	70	72	74	76	80	83	84	84	84	84	84
AR21	0	7	9	11	15	16	19	22	26	28	33	37
AR8	0	50	60	70	76	80	84	87	93	95	98	91
AR15	0	40	81	57	35	22	20	13	9	5	4	1
AR17	0	10	15	20	25	30	35	40	45	50	55	60
AR1	0	10	15	30	50	70	80	90	94	96	98	100
AR4	0	15	26	36	45	56	65	76	83	93	86	75
TM10	0	50	70	90	100	100	100	100	100	100	100	100
Mean	0	28	39	44	48	53	54	55	57	59	61	61
Normalized	0	46	63	72	79	87	89	91	94	97	100	99



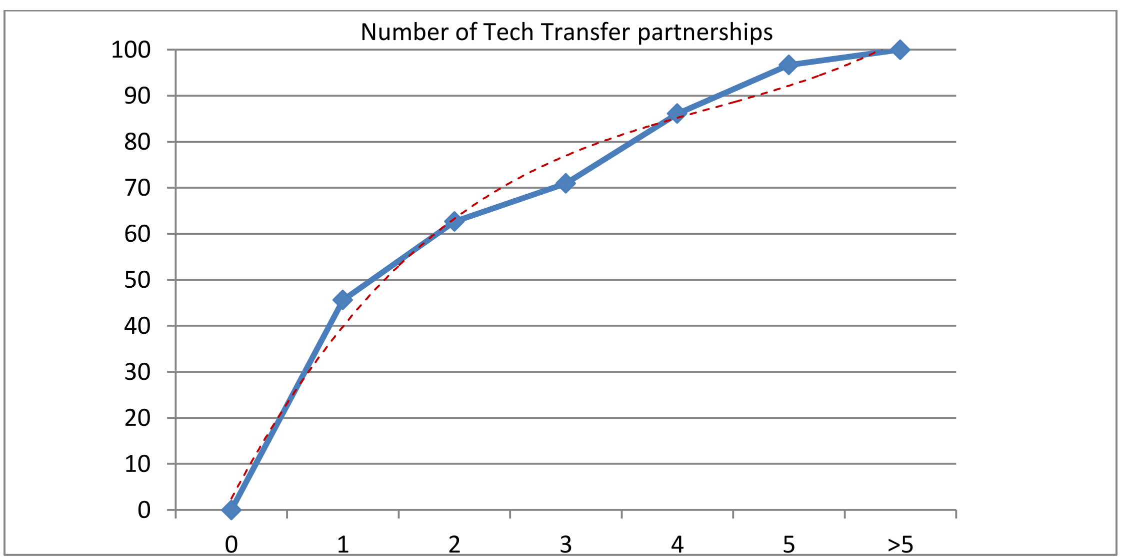
APPENDIX I -38: DESIRABILITY CURVE OF "AVERAGE NUMBER OF PROJECTS SUPPORTED AT A TECHNOLOGY COMMERCIALIZATION SUPPORT FACILITY" METRIC

	Average number of projects supported at one of the commercialization facilities						
Expert	*0*	*0<n≤10*	*10<n≤20*	*20<n≤30*	*30<n≤40*	*40<n≤50*	*n>50*
AR5	0	40	50	48	49	0	0
TM2	0	20	40	60	80	100	100
AR9	0	15	23	35	52	72	96
AR10	0	4	25	56	69	90	100
AR18	0	30	65	90	100	95	70
AR6	0	10	20	30	40	40	50
AR11	0	14	24	30	30	25	21
AR16	0	53	54	55	57	57	57
TM6	0	10	50	60	56	49	43
AR21	0	3	5	6	8	11	14
AR8	0	60	70	80	90	96	100
AR15	0	7	38	65	100	35	1
AR17	0	10	15	20	25	30	35
AR1	0	20	40	60	80	90	100
AR4	0	36	52	74	40	21	2
TM10	0	50	90	95	100	100	75
Mean	0	24	41	54	61	57	54
Normalized	0	39	68	89	100	93	89



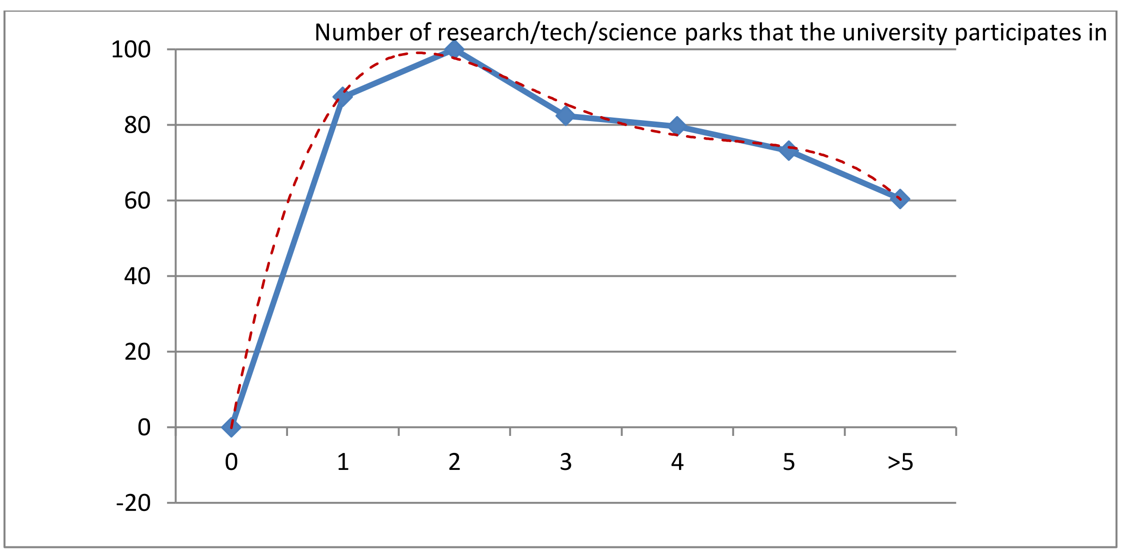
APPENDIX I -39: DESIRABILITY CURVE OF "TECH TRANSFER PARTNERSHIPS" METRIC

	Number of Tech Transfer partnerships						
Expert	*0*	*1*	*2*	*3*	*4*	*5*	*>5*
AR5	0	47	60	66	78	71	35
TM2	0	20	40	60	80	100	100
AR9	0	23	37	51	66	80	95
AR10	0	3	18	35	61	78	100
AR18	0	40	75	88	97	100	100
AR6	0	10	14	24	29	34	61
AR11	0	15	14	26	25	24	20
AR16	0	32	35	37	38	38	39
TM6	0	13	15	18	20	38	39
AR21	0	5	7	18	20	18	13
AR8	0	72	86	10	12	18	27
AR15	0	17	27	92	96	98	100
AR17	0	10	15	40	81	98	100
AR1	0	50	85	20	25	30	35
AR4	0	0	0	26	55	74	88
TM10	0	100	100	100	80	70	50
Mean	0	29	39	44	54	61	63
Normalized	0	46	63	71	86	97	100



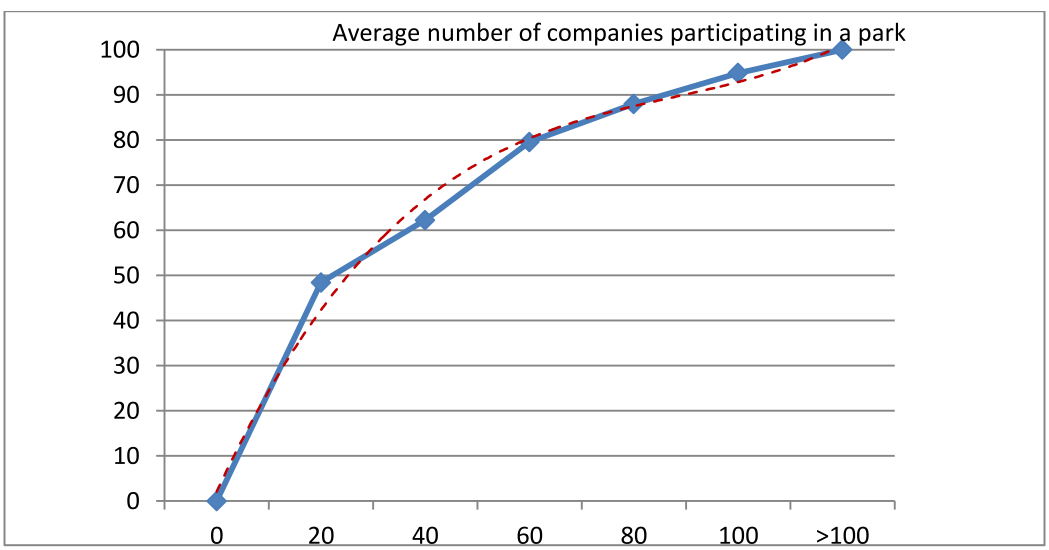
APPENDIX I -40: DESIRABILITY CURVE OF "NUMBER OF RESEARCH/TECH/SCIENCE PARKS THE UNIVERSITY PARTICIPATES IN" METRIC

	Number of research/tech/science parks that the university participates in						
Expert	*0*	*1*	*2*	*3*	*4*	*5*	*>5*
AR5	0	14	34	50	49	10	0
TM2	0	100	100	100	100	100	0
AR9	0	33	43	51	58	66	70
AR10	0	20	46	66	71	67	60
AR18	0	80	100	100	80	60	30
AR6	0	40	50	50	50	50	50
AR11	0	10	15	20	13	10	5
AR16	0	41	43	46	47	48	50
TM6	0	50	50	50	45	40	30
AR21	0	10	19	28	35	42	47
AR8	0	80	85	87	90	91	87
AR15	0	50	94	35	16	3	0
AR17	0	100	75	75	75	75	100
AR1	0	95	100	100	100	100	100
AR4	0	87	87	0	0	0	0
TM10	0	100	100	0	0	0	0
Mean	0	57	65	54	52	48	39
Normalized	0	87	100	82	80	73	60



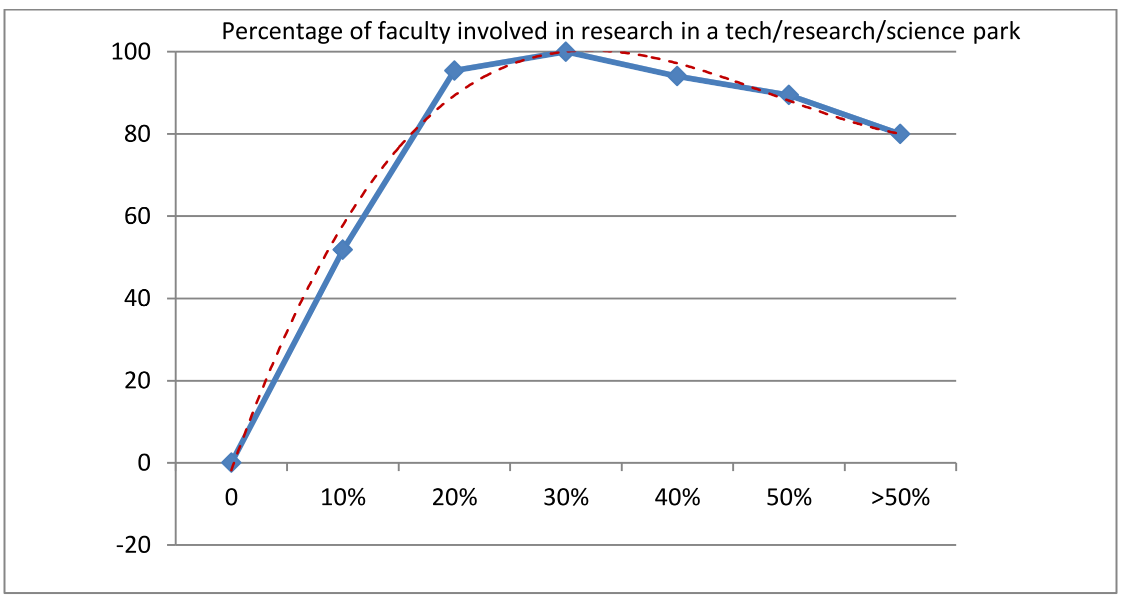
APPENDIX I -41: DESIRABILITY CURVE OF "AVERAGE NUMBER OF COMPANIES PARTICIPATE IN A PARK" METRIC

	Average number of companies participating in a park						
Expert	*0*	*20*	*40*	*60*	*80*	*100*	*>100*
AR5	0	26	50	55	48	34	32
TM2	0	20	40	60	80	100	100
AR9	0	28	51	67	77	86	96
AR10	0	26	67	83	81	78	73
AR18	0	40	60	80	100	100	100
AR6	0	20	40	50	60	70	90
AR11	0	20	30	35	35	30	23
AR16	0	42	43	45	47	49	50
TM6	0	20	40	100	94	95	91
AR21	0	13	18	25	40	60	81
AR8	0	71	81	88	92	97	100
AR15	0	98	4	3	4	4	0
AR17	0	11	30	40	55	75	90
AR1	0	25	50	70	80	90	100
AR4	0	53	63	73	84	93	98
TM10	0	80	95	100	100	100	100
Mean	0	37	48	61	67	73	77
Normalized	0	48	62	80	88	95	100



APPENDIX I -42: DESIRABILITY CURVE OF "NUMBER OF FACULTY MEMBERS PARTICIPATE IN THE PARKS" METRIC

	Percentage of faculty involved in research in a tech/research/science park						
Expert	*0*	*10%*	*20%*	*30%*	*40%*	*50%*	*>50%*
AR9	0	9	18	27	36	46	36
AR10	0	6	24	41	74	82	80
AR18	0	40	60	80	100	100	100
AR6	0	50	56	60	60	60	50
AR11	0	15	20	25	37	24	17
AR16	0	38	40	42	43	44	45
TM6	0	40	100	80	65	51	20
AR21	0	19	20	21	23	24	26
AR8	0	40	43	47	50	50	40
AR15	0	20	74	36	8	3	0
AR17	0	5	20	30	40	45	50
AR1	0	75	95	95	50	30	25
AR4	0	16	35	55	9	2	2
TM10	0	10	100	100	100	100	100
Mean	0	27	50	53	50	47	42
Normalized	0	52	95	100	94	89	80



APPENDIX J: DATA ANALYSIS

APPENDIX J -1: ACTUAL VALUES AND CONVERTED DESIRABILITY VALUES OF THE METRICS FOR PORTLAND STATE UNIVERSITY

TT Mechanism (T)	Metric (E)	PSU	
		V(E)	D(E)
T1.1. Informational materials	- Number of online material forms. ($E_{1.1.1}$), including: website, e-newsletter,social network sites (Facebook, Twitter, Linkedin,etc)	2*	60
	- Types of printed materials distributed to public. ($E_{1.1.2}$), including: brochures, newsletters,flyers,posters,banners, etc.	2*	78
T1.2. Technology expositions	- Number of technology expositions in which the university participates in a given year, ($E_{1.2.1}$).	0*	0
T1.3. Publications	- Average number of publications (journal papers) per researcher in a given year, ($E_{1.3.1}$).	1*	20
	- Average number of citations of academic papers per researcher in a given year, ($E_{1.3.2}$).	30	80
T1.4. Conferences	- Average number of technical conference presentations per researcher in a given year, ($E_{1.4.1}$).	2*	50
	- Average number of citations to conference papers per researcher in a given year ($E_{1.4.2}$).	30	85
T1.5. Industry seminars, workshops, presentations	- Number of seminars, workshops or presentations in in companies or industry meetings provided per researcher in a given year, ($E_{1.5.1}$).	1	55
	- Average number of attendants in an industry presentation made by university researchers in a given year, ($E_{1.5.2}$).	50	60
T2.1. Professional organizations	- Percentage of university researchers with memberships in professional organizations related to their field in a given year, %, ($E_{2.1.1}$).	80	90
	- Average number of professional organizations in which a researcher has memberships in a given year, ($E_{2.1.2}$).	1	60
T3.1. Industry employee education & training	- Percentage of students employed by industry in a given year~~,~~ (%), ($E_{3.1.1}$).	20	90
	- Percentage of faculty members conducting short training courses for industry in a given year, ($E_{3.1.2}$).	20	80
T3.2. Joint supervision of students	- Percentage of students jointly supervised by faculty members and industry advisors in a given year, %, ($E_{3.2.1}$).	5	50

T4.1. Student internship	- Percentage of students with internships in industry in a given year, %, ($E_{4.1.1}$).	20	65
T4.2. University graduate hiring by industry	- Percentage of university graduates hired by technology based industries in a given year, %, ($E_{4.2.1}$).	70	90
4.3. Faculty members with dual positions	- Percentage of faculty members holding positions both at the university and a technological firm in a given year, %, ($E_{4.3.1}$).	10	40
T4.4. Temporary researcher exchange	- Percentage of university researchers exchanged temporarily to industry in a given year, %, ($E_{4.4.1}$).	1	20
T4.5. Faculty members moving to industry	- Percentage of university researchers moving permanently to industry in a given year, %, ($E_{4.5.1}$).	1	80
T5.1. Advisory committees	- Percentage of university researchers serving in advisory committees in industry in a given year, %, ($E_{5.1.1}$).	10	60
T5.2. Consulting	- Percentage of university researchers providing consulting to industry in a given year, ($E_{5.2.1}$).	10	55
	- Average number of consulting agreements with industry performed by a university researcher in a given year, ($E_{5.2.2}$).	1	58
T6.1. Materials Transfer Agreements (MTAs)	- Number of outbound MTAs undertaken at the university in a given year, ($E_{6.1.1}$).	5*	15
T6.2. Sharing of university facilities	- Number of companies using university owned research facilities in a given year, ($E_{6.2.1}$).	20	55
T7.1. Industry sponsored research	- Number of research projects sponsored by industry in a given year, ($E_{7.1.1}$).	20*	20
	- Average size of industry-sponsored research in a given year, $. ($E_{7.1.2}$).	230K*	80
T7.2. Joint research	- Number of joint research projects between university and industry in a given year, ($E_{7.2.1}$).	1	30
T7.3. Research alliance/ research consortium	- Number of existing research alliances /consortia established between university and industry in a given year, ($E_{7.3.1}$).	0	0
	- Percentage of university researchers participating in those initiatives in a given year, %, ($E_{7.3.3}$).	0	0
	- Average number of companies involved in a research initiative in a given year, ($E_{7.3.4}$).	0	0
T8.1. Licensing	- Number of new licenses executed in a given year, ($E_{8.1.1}$).	22*	45
	- Average income (royalty) of an executed license, in thousands of dollars in a given year, ($E_{8.1.2}$).	450*	100
	- Number of new technologies transferred to industry in	8*	25

	a given year, ($E_{8.1.3}$).		
T9.1. Start-up/Spin-off	- Number of new startup companies formed in a given year, ($E_{9.1.1}$).	2*	20
	- Percentage of researchers participating in startups in a given year, %, (E9.1.2).	3*	35
T10.1. TTO	- Number of licensing FTEs in TTO in a given year, ($E_{9.1.1}$).	3.5*	50
T10.2.Technology commercialization support facilities	- Total number of tech commercialization support centers/programs existing at the university in a given year, such as: • incubator • commercialization center • tech development center • entrepreneurship center • proof of concept center • seed fund program/center • tech. maturation fund • entrepreneur-in-residence program • venture pitch competition ($E_{.10,2.1}$).	3*	72
	- Average number of existing projects supported by one of these facilities in a given year, ($E_{10.2.2}$).	5*	40
T.10.3. Tech transfer Intermediary partnership	- Number of existing TT intermediaries with whom the university has partnerships in a given year ($E_{10.3.1}$).	3*	70
T10.4. Research / Technology/ Science parks	- Number of existing research /technology /science parks in which the university participates in a given year, ($E_{10.4.1}$).	0*	0
	- Average number of existing companies in a research/technology/science park in which the university participates in a given year, ($E_{10.4.2}$).	0*	0
	- Percentage of university researchers doing research at the research/ technology/ science parks in a given year, %, ($E_{10.4.3}$)	0*	0

(*) data obtained from PSU sources

V(E): Actual value of the metric

D(E) : Desirability value of the metric converted from the actual value using the desirability curve

APPENDIX J-2: UNIVERSITIES WITH DIFFERENT UKTT ORIENTATIONS

UA1		"UA2 (PSU)"		"UA3"		Scenario 1: "Knowledge orientation"		Scenario 2: "Innovation orientation"		Scenario 3: "Economy orientation"		Scenario 4: "Culture orientation"		Scenario 5: "Finance orientation"		Scenario 6: "Balanced orientation"	
Mec	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*
T8.1	59.55%	T8.1	27.62%	T2.1	14.89%	T2.1	12.83%	T2.1	15.20%	T2.1	16.32%	T2.1	16.14%	T8.1	76.04%	T8.1	21.98%
T9.1	15.84%	T2.1	11.15%	T8.1	14.27%	T3.1	12.35%	T3.1	10.87%	T3.1	10.65%	T8.1	15.80%	T9.1	19.98%	T2.1	12.55%
T2.1	4.33%	T3.1	8.46%	T3.1	10.75%	T6.2	8.91%	T8.1	8.95%	T5.1	8.82%	T3.1	11.54%	T2.1	0.70%	T3.1	9.39%
T3.1	3.31%	T9.1	7.98%	T7.1	5.75%	T8.1	8.32%	T4.2	8.08%	T5.2	8.58%	T7.1	9.66%	T3.1	0.52%	T9.1	6.46%
T4.2	1.82%	T6.2	4.86%	T4.2	5.44%	T4.2	6.80%	T6.2	7.97%	T8.1	7.80%	T7.2	5.55%	T6.2	0.28%	T6.2	5.11%
T7.1	1.71%	T4.2	4.68%	T6.2	4.66%	T7.1	5.34%	T4.5	5.93%	T6.2	7.27%	T4.2	5.25%	T4.2	0.28%	T4.2	5.01%
T6.2	1.59%	T7.1	3.79%	T3.2	4.40%	T3.2	5.06%	T4.1	4.57%	T3.2	4.36%	T3.2	4.73%	T7.1	0.24%	T7.1	4.39%
T3.2	1.35%	T3.2	3.47%	T9.1	4.18%	T4.5	4.99%	T3.2	4.46%	T4.2	4.07%	T4.5	3.85%	T3.2	0.21%	T3.2	3.85%
T4.5	1.34%	T4.5	3.43%	T4.5	3.99%	T1.4	4.22%	T9.1	4.16%	T7.1	3.51%	T1.4	3.41%	T4.5	0.20%	T4.5	3.68%
T1.4	1.04%	T1.4	2.68%	T7.2	3.30%	T4.1	3.84%	T1.4	3.49%	T1.4	3.14%	T9.1	3.39%	T1.4	0.16%	T1.4	2.95%
T4.1	1.03%	T4.1	2.64%	T1.4	3.29%	T9.1	3.84%	T4.3	3.44%	T4.5	2.99%	T1.1	3.02%	T4.1	0.16%	T4.1	2.83%
T7.2	0.98%	T1.1	2.37%	T4.1	3.07%	T1.1	3.74%	T1.1	3.09%	T1.1	2.78%	T4.1	2.97%	T1.1	0.15%	T1.1	2.61%
T1.1	0.92%	T7.2	2.18%	T1.1	2.92%	T1.5	3.29%	T7.1	2.97%	T9.1	2.66%	T1.5	2.65%	T7.2	0.14%	T7.2	2.52%
T1.5	0.81%	T1.5	2.09%	T1.5	2.56%	T7.2	3.07%	T1.5	2.71%	T1.5	2.45%	T10.3	2.25%	T1.5	0.13%	T1.5	2.30%
T4.3	0.77%	T4.3	1.99%	T5.1	2.44%	T4.3	2.89%	T10.3	2.41%	T4.1	2.30%	T4.3	2.23%	T4.3	0.12%	T4.3	2.13%
T10.3	0.59%	T1.3	1.50%	T5.2	2.38%	T1.3	2.37%	T10.1	2.27%	T7.2	2.02%	T10.1	2.12%	T5.1	0.11%	T5.1	1.96%
T1.3	0.58%	T5.1	1.49%	T4.3	2.31%	T6.1	2.15%	T10.2	2.24%	T1.3	1.76%	T10.2	2.09%	T5.2	0.11%	T5.2	1.91%
T10.1	0.55%	T10.3	1.46%	T10.3	1.90%	T10.3	1.60%	T1.3	1.95%	T6.1	1.76%	T1.3	1.91%	T1.3	0.09%	T1.3	1.65%
T10.2	0.55%	T5.2	1.45%	T1.3	1.84%	T10.1	1.51%	T6.1	1.93%	T4.3	1.73%	T4.4	0.91%	T10.3	0.09%	T10.3	1.61%
T6.1	0.38%	T10.1	1.37%	T10.1	1.79%	T10.2	1.49%	T7.2	1.71%	T10.3	1.50%	T6.2	0.26%	T10.1	0.08%	T10.1	1.51%
T5.1	0.32%	T10.2	1.36%	T10.2	1.77%	T4.4	1.18%	T4.4	1.41%	T10.1	1.42%	T5.1	0.10%	T10.2	0.08%	T10.2	1.50%
T4.4	0.32%	T6.1	1.17%	T6.1	1.13%	T5.1	0.10%	T5.1	0.09%	T10.2	1.40%	T5.2	0.10%	T6.1	0.07%	T6.1	1.24%
T5.2	0.31%	T4.4	0.81%	T4.4	0.95%	T5.2	0.10%	T5.2	0.09%	T4.4	0.71%	T6.1	0.06%	T4.4	0.05%	T4.4	0.87%

T1.2	0.00%	T1.2	0.00%	T1.2	0.00%	T1.2	0.00%	T1.2	0.00%	T1.2	0.00%	T1.2	0.00%	T1.2	0.00%	T1.2	0.00%
T7.3	0.00%	T7.3	0.00%	T7.3	0.00%	T7.3	0.00%	T7.3	0.00%	T7.3	0.00%	T7.3	0.00%	T7.3	0.00%	T7.3	0.00%
T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%

Note:

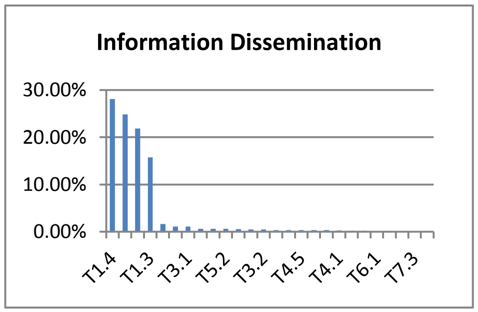
%EI : percentage of the mechanism's contribution to the final UKTT Effectiveness Index, calculated in Column 17 in Table 16

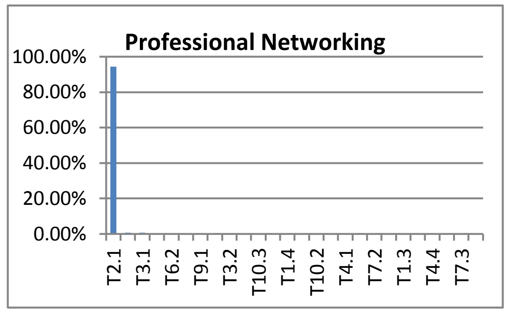
APPENDIX J-3: RESULTS OF THE 12 UKTT MECHANISM GROUP SCENARIOS

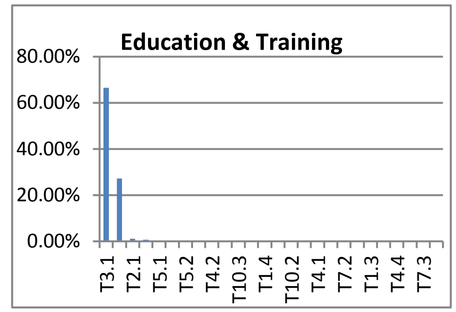
Case 1 "Information"		Case 2 "Networking"		Case 3 "Edu.&Train"		Case 4 "Per.movement "		Case 5 "Consulting"		Case 6 "Res.sharing"		Case 7 : "Research"		Case 8 "Licensing"		Case 9 "Startup"		Case 10 "Infrastructure"		Case 10 "Balanced"		Case 11 "Baseline"	
Mec	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*	*Mec*	*%EI*
T1.4	28.09%	T2.1	94.36%	T3.1	66.52%	T4.2	31.95%	T5.1	46.79%	T6.2	70.65%	T7.1	52.78%	T8.1	91.44%	T9.1	83.07%	T10.3	31.29%	T2.1	15.53%	T8.1	27.62%
T1.1	24.89%	T8.1	0.70%	T3.2	27.26%	T4.5	23.46%	T5.2	45.54%	T6.1	17.09%	T7.2	30.33%	T2.1	1.49%	T2.1	2.77%	T10.1	29.46%	T8.1	10.50%	T2.1	11.15%
T1.5	21.87%	T3.1	0.67%	T2.1	1.13%	T4.1	18.06%	T2.1	1.35%	T2.1	2.05%	T2.1	2.76%	T3.1	0.96%	T8.1	1.87%	T10.2	29.14%	T3.1	10.08%	T3.1	8.46%
T1.3	15.73%	T5.1	0.40%	T8.1	0.76%	T4.3	13.58%	T8.1	0.91%	T8.1	1.39%	T8.1	1.87%	T5.1	0.57%	T3.1	1.80%	T2.1	1.72%	T5.1	5.92%	T9.1	7.98%
T2.1	1.62%	T6.2	0.39%	T5.1	0.43%	T4.4	5.56%	T3.1	0.87%	T3.1	1.33%	T3.1	1.79%	T6.2	0.56%	T5.1	1.06%	T8.1	1.16%	T6.2	5.87%	T6.2	4.86%
T8.1	1.09%	T5.2	0.38%	T6.2	0.43%	T2.1	1.31%	T6.2	0.51%	T5.1	0.78%	T5.1	1.05%	T5.2	0.55%	T6.2	1.05%	T3.1	1.12%	T5.2	5.76%	T4.2	4.68%
T3.1	1.05%	T9.1	0.34%	T5.2	0.42%	T8.1	0.88%	T9.1	0.44%	T5.2	0.76%	T6.2	1.04%	T9.1	0.49%	T5.2	1.03%	T5.1	0.66%	T9.1	5.11%	T7.1	3.79%
T5.1	0.62%	T4.2	0.28%	T9.1	0.37%	T3.1	0.85%	T4.2	0.36%	T9.1	0.68%	T5.2	1.03%	T4.2	0.40%	T4.2	0.74%	T6.2	0.65%	T4.2	4.17%	T3.2	3.47%
T6.2	0.61%	T3.2	0.28%	T4.2	0.30%	T5.1	0.50%	T3.2	0.36%	T4.2	0.55%	T9.1	0.91%	T3.2	0.39%	T3.2	0.74%	T5.2	0.64%	T3.2	4.13%	T4.5	3.43%
T5.2	0.60%	T7.1	0.22%	T7.1	0.24%	T6.2	0.49%	T7.1	0.28%	T3.2	0.55%	T4.2	0.74%	T7.1	0.31%	T7.1	0.58%	T9.1	0.57%	T7.1	3.26%	T1.4	2.68%
T9.1	0.53%	T10.3	0.21%	T10.3	0.22%	T5.2	0.49%	T10.3	0.27%	T7.1	0.43%	T3.2	0.73%	T10.3	0.30%	T10.3	0.55%	T4.2	0.46%	T10.3	3.10%	T4.1	2.64%
T4.2	0.43%	T4.5	0.20%	T4.5	0.22%	T9.1	0.43%	T4.5	0.27%	T10.3	0.41%	T10.3	0.55%	T4.5	0.29%	T4.5	0.55%	T3.2	0.46%	T4.5	3.06%	T1.1	2.37%
T3.2	0.43%	T1.4	0.20%	T1.4	0.22%	T3.2	0.35%	T1.4	0.26%	T4.5	0.40%	T4.5	0.54%	T1.4	0.28%	T1.4	0.53%	T7.1	0.36%	T1.4	2.96%	T7.2	2.18%
T7.1	0.34%	T10.1	0.20%	T10.1	0.21%	T7.1	0.27%	T10.1	0.25%	T1.4	0.39%	T1.4	0.53%	T10.1	0.28%	T10.1	0.52%	T4.5	0.34%	T10.1	2.92%	T1.5	2.09%
T10.3	0.32%	T10.2	0.19%	T10.2	0.21%	T10.3	0.26%	T10.2	0.25%	T10.1	0.39%	T10.1	0.52%	T10.2	0.28%	T10.2	0.52%	T1.4	0.33%	T10.2	2.89%	T4.3	1.99%
T4.5	0.32%	T1.1	0.18%	T1.1	0.19%	T1.4	0.25%	T1.1	0.23%	T10.2	0.38%	T10.2	0.51%	T1.1	0.25%	T1.1	0.47%	T1.1	0.29%	T1.1	2.63%	T1.3	1.50%
T10.1	0.30%	T4.1	0.16%	T4.1	0.17%	T10.1	0.25%	T4.1	0.20%	T1.1	0.35%	T1.1	0.47%	T4.1	0.23%	T4.1	0.42%	T4.1	0.26%	T4.1	2.36%	T5.1	1.49%
T10.2	0.30%	T1.5	0.15%	T1.5	0.17%	T10.2	0.24%	T1.5	0.20%	T4.1	0.31%	T4.1	0.42%	T1.5	0.22%	T1.5	0.41%	T1.5	0.26%	T1.5	2.31%	T10.3	1.46%
T4.1	0.25%	T7.2	0.13%	T7.2	0.14%	T1.1	0.22%	T7.2	0.16%	T1.5	0.31%	T1.5	0.41%	T7.2	0.18%	T7.2	0.33%	T7.2	0.21%	T7.2	1.87%	T5.2	1.45%
T7.2	0.20%	T4.3	0.12%	T4.3	0.13%	T1.5	0.19%	T4.3	0.15%	T7.2	0.25%	T4.3	0.32%	T4.3	0.17%	T4.3	0.32%	T4.3	0.20%	T4.3	1.77%	T10.1	1.37%
T4.3	0.18%	T1.3	0.11%	T1.3	0.12%	T7.2	0.16%	T1.3	0.14%	T4.3	0.23%	T1.3	0.30%	T1.3	0.16%	T1.3	0.30%	T1.3	0.18%	T1.3	1.66%	T10.2	1.36%
T6.1	0.15%	T6.1	0.09%	T6.1	0.10%	T1.3	0.14%	T6.1	0.12%	T1.3	0.22%	T6.1	0.25%	T6.1	0.14%	T6.1	0.25%	T6.1	0.16%	T6.1	1.42%	T6.1	1.17%
T4.4	0.08%	T4.4	0.05%	T4.4	0.05%	T6.1	0.12%	T4.4	0.06%	T4.4	0.10%	T4.4	0.13%	T4.4	0.07%	T4.4	0.13%	T4.4	0.08%	T4.4	0.72%	T4.4	0.81%

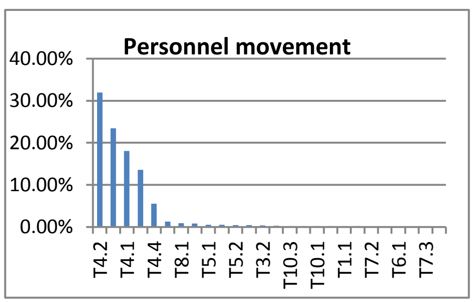
T1.2	0.00%	T1.2	0.00%	T1.2	0.00%	T1.2	0.00%	T1.2	0.00%	T1.2	0.00%	T1.2	0.00%	T1.2	0.00%	T1.2	0.00%	T1.2	0.00%	T1.2	0.00%	T1.2	0.00%
T7.3	0.00%	T7.3	0.00%	T7.3	0.00%	T7.3	0.00%	T7.3	0.00%	T7.3	0.00%	T7.3	0.00%	T7.3	0.00%	T7.3	0.00%	T7.3	0.00%	T7.3	0.00%	T7.3	0.00%
T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%	T.10.4	0.00%
UKTTEI																							
	47.7		**74.4**		**68.4**		**59**		**57.2**		**37.5**		**27.9**		**51.9**		**27.8**		**44.8**		**49.7**		**47.4**

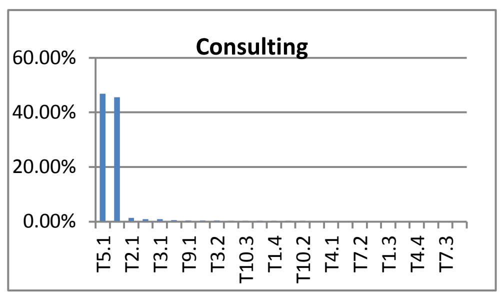
APPENDIX J-4: DISTRIBUTION OF CONTRIBUTION VALUES IN 12 MECHANISM GROUP SCENARIOS

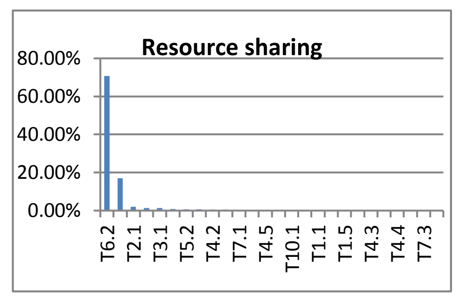


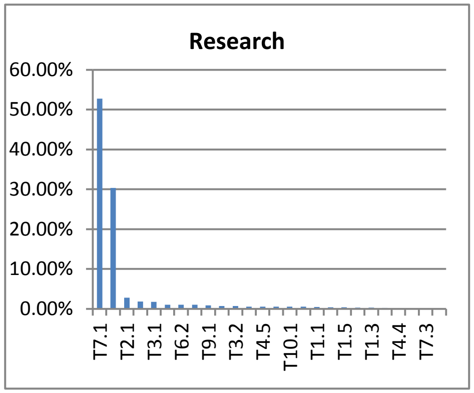


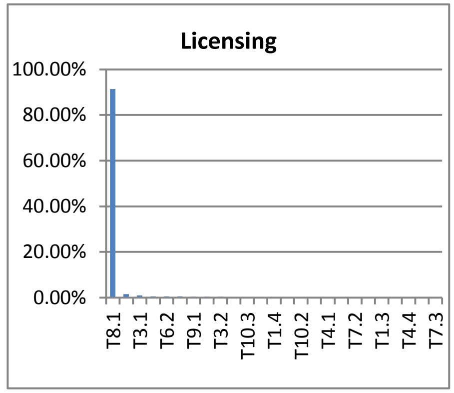


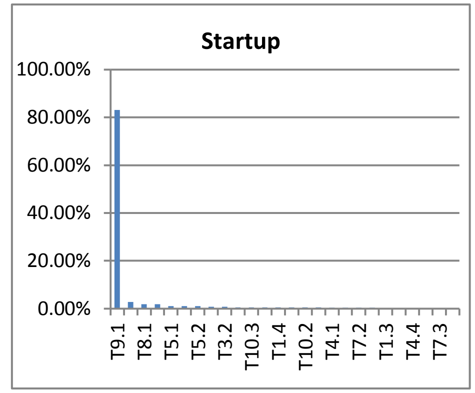


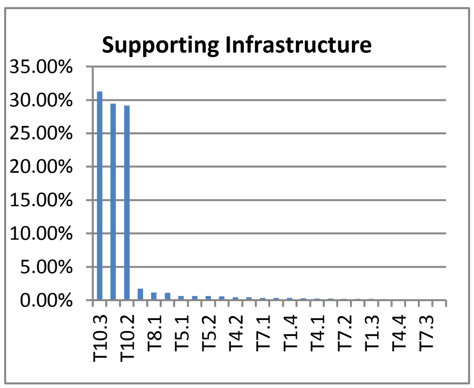


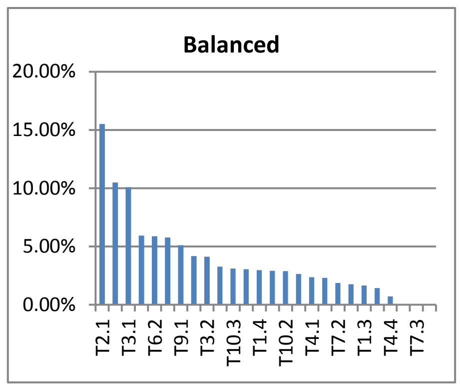


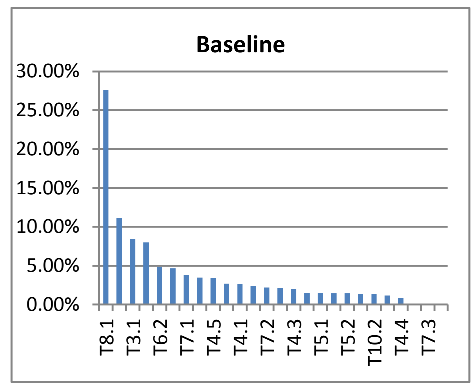

Research
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
T7.1 T2.1 T3.1 T6.2 T9.1 T3.2 T4.5 T10.1 T1.1 T1.5 T1.3 T4.4 T7.3


Licensing
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
T8.1 T3.1 T6.2 T9.1 T3.2 T10.3 T1.4 T10.2 T4.1 T7.2 T1.3 T4.4 T7.3


Startup
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
T9.1 T8.1 T5.1 T5.2 T3.2 T10.3 T1.4 T10.2 T4.1 T7.2 T1.3 T4.4 T7.3


Supporting Infrastructure
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
T10.3 T10.2 T8.1 T5.1 T5.2 T4.2 T7.1 T1.4 T4.1 T7.2 T1.3 T4.4 T7.3


Balanced
20.00%
15.00%
10.00%
5.00%
0.00%
T2.1 T3.1 T6.2 T9.1 T3.2 T10.3 T1.4 T10.2 T4.1 T7.2 T1.3 T4.4 T7.3


Baseline
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
T8.1 T3.1 T6.2 T7.1 T4.5 T4.1 T7.2 T4.3 T5.1 T5.2 T10.2 T4.4 T7.3

APPENDIX J-5: SENSITIVITY ANALYSIS OF THE BASELINE (PSU)

			Current			Incremental 1			Incremental 2			Incremental 3			Incremental 4			Incremental 5		
No.	Mechanism (T)	Indicator/Metric	V(E)	D(E)	**EI**	V(E)	D(E)	EI	V(E)	D(E)	EI	V(E)	D(E)	EI	V(E)	D(E)	EI	V(E)	D(E)	EI
1	T8.1. Licensing	E8.1.1 No. of licenses	22	*45*	**47.40**	38	*72*	**49.19**	54	*78*	**49.59**	70	*84*	**50.00**	86	*90*	**50.41**	102	*100*	**51.08**
		E8.1.2 Average income	450	*100*	**47.40**	450	*100*	**47.40**	450	*100*	**47.40**	450	*100*	**47.40**	450	*100*	**47.40**	450	*100*	**47.40**
		E8.1.3 No. of technologies	8	*25*	**47.40**	28	*58*	**51.00**	48	*72*	**52.54**	68	*83*	**53.76**	88	*89*	**54.42**	108	*100*	**55.63**
		Aggregated:			**47.36**			**52.83**			**54.78**			**56.40**			**57.47**			**59.36**
2	T9.1. Startups	E9.1.1 No. of startups	2	*20*	**47.40**	8	*70*	**52.12**	14	*78*	**52.88**	20	*90*	**54.02**	26	*96*	**54.60**	32	*100*	**54.98**
		E9.1.2 % faculty involved	3	*35*	**47.40**	6	*62*	**48.80**	9	*78*	**49.66**	12	*82*	**49.88**	16	*92*	**50.41**	20	*100*	**50.84**
		Aggregated:			**47.40**			**53.57**			**55.18**			**56.54**			**57.65**			**58.46**
3	T7.3. Research alliances	E7.3.1. No. of alliances	0	*0*	**47.40**	2	*56*	**48.01**	4	*76*	**48.24**	6	*85*	**48.35**	8	*92*	**48.43**	10	*100*	**48.52**
		E7.3.2. % faculty involved	0	*0*	**47.40**	4	*68*	**48.31**	8	*88*	**48.59**	12	*96*	**48.70**	16	*99*	**48.74**	20	*100*	**48.76**
		E.7.3.3 No. of companies	0	*0*	**47.40**	3	*80*	**48.41**	6	*90*	**48.55**	9	*99*	**48.66**	12	*99*	**48.66**	15	*100*	**48.68**
		Aggregated:			**47.40**			**50.02**			**50.66**			**51.00**			**51.12**			**51.24**
4	T6.1. MTAs	E.6.1. No. of MTAs	5	*15*	**47.40**	35	*37*	**48.17**	65	*55*	**48.84**	95	*74*	**49.55**	125	*85*	**49.95**	155	*100*	**50.51**
5	T7.2. Joint research	E7.2.1 No. of projects	1	*30*	**47.40**	17	*58*	**48.32**	33	*74*	**48.87**	49	*89*	**49.39**	65	*92*	**49.49**	81	*100*	**49.76**

Note: Each increment of change is one fifth of the difference between the current value and the value with highest desirability value of the metric